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A Method to Quantify Road Safety Audit Data and Results

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A METHOD TO QUANTIFY ROAD SAFETY AUDIT DATA AND RESULTS

by

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ABSTRACT

A Method to Quantify Road Safety Audit Data and Results

by

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The research presented in this thesis is the result of field data collection conducted by the Utah Local Technical Assistance Program (Utah LTAP) in conjunction with the Utah Department of Transportation. The first step of the research was data collection from 18 road safety audits conducted throughout the state of Utah. These Road Safety Audits (RSA's) provided a wide variety of data that was used for the validation of the road safety audit quantification methodology. The purpose of this research is to provide quantification to the RSA process that will increase the benefits gained from implementing the RSA recommendations. Benefits derived from the implementation of RSA recommendations were found by assessing the change of risk from before and after safety improvements. The RSA quantification tool was developed to analyze projects in both urban and rural settings. The implementation of the RSA tool will help practitioners show the benefits that can be gained from the safety recommendations and help decision makers in allocating funds to the areas that pose the most risk. The tool will show the

difference in risk that the improvements make and the cost effectiveness of different project alternatives.

(94 pages)

PUBLIC ABSTRACT

A Method to Quantify Road Safety Audit Data and Results

The Utah Local Technical Assistant Program (Utah LTAP) with assistance from the Utah Department of Transportation conducted over 18 Road Safety Audit (RSA's) projects on existing roadways. The projects ranged from roads on minor rural collectors to major urban collectors as well as intersections and unpaved roads. Part of this research shows the lessons learned and the common recommendations for each type of facility.

After all the RSA projects were conducted a tool was developed to help quantify the risk for drivers and pedestrians on the roadway. The tool is able to analyze the risk before and after recommended safety improvements are made which helps show the benefit of each safety recommendation. When the tool is used on multiple roads in a network, decision makers can find the highest risk roads and concentrate their safety improvements on those roads.

Joshua Reid Jones

DEDICATION

This thesis is dedicated to all of the mentors that I have had in my life. My mother, Shauna, for her optimistic view of life and never letting me give up. My father, Nick, for showing me how to always conduct yourself honestly and for guiding me into civil engineering. My sisters (Jada, Tandi, and Camie) for their unconditional love and support. My brothers-in-law, nieces, and nephews, for providing me with a rock solid base from which to go after my dreams. Finally to all my friends and teachers I have had in my life, they have always shown me love and encouragement. I love all of you.

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Joshua Reid Jones

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CHAPTER 1

INTRODUCTION

Everyday thousands of people are killed and injured on roads in the United States. The UN Secretary-General Ban Ki-moon wrote in 2008, “This year, more than one million people across the world will die from road traffic injuries. This total includes about 400,000 people under 25 years old, and road traffic crashes are the leading cause of death for 10- to 24-year-olds. Several million more men, women and young people will be injured or disabled. In addition to the human suffering, the annual cost of road traffic injuries worldwide runs to hundreds of billions of dollars.” Crashes on the world’s roadways are expected to almost double in the next 10 years (UNECE 2008). In order combat the problem of roadway safety, the UN General Assembly declared the decade 2011-2020 as the “Decade of Action for Road Safety” with the goal to stabilize and then reduce traffic fatalities around the world by increasing activities conducted at national, regional, and global levels (UNDESA 2010).

U.S. Transportation Secretary Ray LaHood released the updated 2009 fatality and injury data showing that highway deaths fell to 33,808 for the year, the lowest number since 1950 (NHTSA 2010). The record-breaking decline in traffic fatalities occurred even while estimated vehicle miles traveled in 2009 increased by 0.2 percent over 2008 levels. “At the Department of Transportation, we are laser-focused on our top priority: safety,” said Secretary LaHood. “Today’s announcement shows that America’s roads are the safest they've ever been. But they must be safer. And we will not rest until they are." (NHTSA 2010)

The newest numbers are encouraging in that roadway fatalities are decreasing but one fatality is still too much. To combat the number of injuries and fatalities, road safety audits (RSA's) have become an increasingly popular approach to improve safety on roadways. Road safety audits are versatile because they can be used to evaluate existing roadways and also roadways in the planning and construction processes. Road safety audits are a proactive way for transportation agencies to diagnose safety deficiencies before crashes and injuries occur. A road safety audit is a formal safety performance examination of a roadway (segment or intersection) in design stage or that currently exists by an independent multidisciplinary team. Recognizing the fact that compromises and constraints occur among the competing interests that typically drive a road project (such as cost, right-of-way, environment, topographic and geotechnical conditions, socioeconomic issues, and capacity/efficiency) an RSA conducted by an independent team enhances the consideration of safety measures by explicitly and exclusively identifying the safety implications of project decisions.

As road safety audits have been implemented by agencies across the country, transportation professionals have realized that they are an effective tool for proactively improving the future safety performance of a roadway during the planning and design stages and for identifying safety issues in existing transportation facilities (FHWA 2006). The RSA process is qualitative in nature so there have been limited quantitative studies of the benefits gained through road safety audit recommendations on existing roadways.

As part of an effort by the Federal Highway Administration (FHWA) to promote the use of road safety audits, the Utah Local Technical Assistance Program (Utah LTAP) was contracted by FHWA to assist local agencies in the conduct of road safety audits in Utah. The research in this thesis focuses on the quantification of data collected in the 18 RSA's conducted throughout Utah and provides a tool to help quantify the risk on the roadway. The tool is incremental applied research and the first step from a qualitative process to a quantification process. The underlining theme of this research is to provide practitioners a methodology to quantify the data and results of a RSA. The expectation is that the tool will provide practitioners and local governments with a way to pick safety projects based on roads with a higher risk score.

The second chapter of the thesis is devoted to a literature review that describes RSA's and details the history of safety audits. The third chapter of the thesis provides descriptions of the 18 road safety audits conducted in Utah as well as the lessons learned through Utah's RSA program. The fourth chapter of the thesis presents the tool to assess and quantify safety risk and benefits gained through safety improvements implemented from RSA recommendations. The final chapter of the thesis provides conclusion from the research and areas for future study. It is believed that the results of this research could provide a model for local agencies nationwide to implement road safety audit recommendations more effectively.

1.1 Research Questions

The major question this research focuses is: "How do you quantify safety risks on a roadway during a RSA review?" Addressing this question effectively requires the ability to identify areas on the road that cause risk and the effect that the risk will have on the safety of the road. This question was addressed by examining data obtained from the RSA projects and finding common safety hazards and determining the amount of risk of each hazard. Once all of the hazards are identified, they can be quantified in the safety quantification tool. The safety quantification tool is useful for decision makers trying to allocate the right amount of money to the areas that provide the best impact for the dollars that are expended. In addition, the quantification tool will be helpful examining risk on roadways that do not have extensive crash histories associated with them. Additionally, risks for pedestrians and bicycles are difficult to assess and to quantify. Usually multiple factors are involved with crashes and can complicate the process of finding solutions. The research will provide guidance which will be helpful to decision makers in the assessment of pedestrian and bicyclist safety. Currently, there is difficulty determining the benefits gained through the RSA process because the majority of roads audited have inadequate crash histories. Additionally it will give practitioners a tool that will help identify the most high risk roadways.

1.2 Research Problem and General Approach

The research described in this thesis will provide guidance to best implement RSA's. First, the literature review consists of an analysis of various RSA processes that have been used internationally and domestically. Additionally a RSA history is outlined to understand how the process came about. Other topics that are covered include: benefits gained through RSA's, other RSA processes, and where RSA's are most beneficial.

Second, Utah's RSA projects will be presented. This will include Salt Lake City's RSA project and the successful implementation of the RSA recommendations. Next, the other 17 are separated into 3 groups: intersections, rural roadways, and urban collectors. The wide range of RSA projects allowed for many lessons to be learned and different approaches to be used. Additionally multiple agencies were used in the RSA inspections team that included UDOT personnel, county workers, city representatives, policeman, and maintenance workers among others. This provided a great training atmosphere for all involved and created a dynamic team that were able to come up with multiple solutions to problems on the road.

Finally, the data collected through the RSA's will be analyzed to determine the benefits that were gained through the RSA program. This was accomplished by creating a tool in excel that quantifies the risk on the roadway before and after the RSA was conducted. In addition, a review was conducted on two rural RSA programs in Wyoming and South Dakota that looked at the benefits gained from their programs. Crash reduction factors and risk ratings will both be incorporated into the risk tool. The quantitative risk tool will have seven focus areas that will identify areas on the roadway that cause risk. The seven focus areas are: Signs, Traffic Control Devices, Pavement, Roadside Hazard, Sight Distance, Cross-Section, and Pedestrian/Bicycle.

To improve decision makers' ability to assess risk on the roadways, transportation professionals require a tool that can look at the complexity of the roadways. This research proposes a six category decision making tool that can help quantify the risk into a quantifiable number that can give the analyst a basis for cost benefit analysis.

1.3 Anticipated Contributions

Since the RSA process is fairly new, research is needed to progress the field. This research is significant in several ways. One contribution of this research will give practitioners and researchers a framework to base their own RSA's on. They will be able to find out what works and what aspects they can make better. One of the biggest successes of the RSA program was lessons learned in implementing RSA recommendations.

The tool will help decision makers allocate money to the most high risk roadways based on a quantitative process and help them understand the benefits gained from the recommendations implemented. This will help practitioners prove the benefit that can be gained by conducting a RSA. It will also help prove that Utah RSA program was a success and that it will be a valuable tool going forward.

1.4 Thesis Organization

This thesis document provides a report on the research conducted over the period of March 2008 to August 2010. The remaining chapters contained in this document are organized with chapters three and four providing the results of the research.

Chapter 2 – Literature Review

Chapter 3 – RSA Case Studies and Lessons Learned.

Chapter 4 – A Tool to Quantify Safety Risk on Roadways.

Chapter 5 – Conclusions and Topics for Further Research.

CHAPTER 2

LITERATURE REVIEW

2.1 Purpose

The purpose of this literature review is to provide background information, the current state of RSA's, and to compile a comprehensive collection of applicable works to support this research.

2.2 Literature Categories

To be able to provide a comprehensive literature review it is necessary to expand on a number of topics. The topics which this literature review covers are: 1) road safety audit history, 2) road safety audit guidelines, 3) practice of RSA's, and 4) literature to help quantify the risk on the roadway. The details and reason each topics are covered is detailed below:

1. Road safety audit history is to show where RSA's were developed and how they have evolved over the years.
2. Road safety audit guidelines that illustrate the RSA process.
3. State of the practice in RSA's domestically and internationally. This will provide a comparison RSA processes around the world and detail of the process used by the Utah LTAP Center.
4. Supporting literature to quantify the risks on the roadway to determine what factors cause a safety risks.

2.3 Road Safety Audit History

Road safety audit procedures were developed in 1989 by British traffic engineers and evolved from a tool used by railway engineers to examine safety issues on railways. RSA's were soon adopted by Australia, New Zealand, Denmark, and many other developed countries in the early 1990s (FHWA 2009a). The development of the road safety audit procedures was refined before adoption by the American transportation community.

In 1996, the FHWA sponsored a tour of Australia and New Zealand to study their road safety audit programs to learn strategies on how to implement road safety audits in the United States. From the lessons learned, FHWA sponsored a road safety audit workshop in St. Louis to develop procedures to be used in the road safety audit pilot program. The first pilot program included thirteen states and provided a basis for use of road safety audits in the United States (Wilson and Lipinski 2004).

As road safety audits have gained popularity in the United States they have also gained recognition and acceptance in other parts of the world. The Asian Development Bank, in collaboration with United Nations Economic Commission for Europe and the World Bank, has recently sponsored the use of road safety audits and have a published their own toolkit to be used in conducting a road safety audit (ADB 2003). Countries around world are starting to realize the low cost tool of saving lives.

There are two different RSA processes that can be used. The first one is the traditional RSA that looks at projects before they are built or operational, Pietrucha et al. (2001) described a road safety audit as a process where a team of experts attempts to identify features of the roadway operating environment as potentially dangerous and work to eliminate or change those features in different parts of the design process. The other RSA process used and the process that is used throughout this research is called Road Safety Audit Reviews (RSARs) and can be defined as "an evaluation of an existing roadway section by an independent team, focusing solely upon safety issues" (Wilson and Lipinski 2004). Most states DOTs have reactive safety programs that focus on high-crash locations or have black spot treatment programs. RSARs are different in that they are proactive in nature and use crash data when available but are not dependent on it. RSARs focuses more on safety issues associated with the roadway, all road users, operating under all environmental conditions, and to identify the safety issues associated with the existing facility (Wilson and Lipinski 2004).

2.4 FHWA Road Safety Audit Guidelines

FHWA in 2006 published RSA guidelines to be used in the United States. The guideline is to assist public agencies develop their own RSA policies and processes. This document was instrumental in developing the RSA process that was used by the Utah LTAP. The guidelines focused on post-construction phase RSA's and the main objective was to "identify road safety issues for different road users that might result in a crash given the operational characteristics of the road in question" (FHWA 2006). The purposes of an RSA on an existing road are to:

- Evaluate all roadway and roadside features, design elements and local conditions that would increase the likelihood and severity of a crash.

- Review firsthand the interaction of various design elements with each other and surrounding road network.
- Observe how road users are interacting with the road facility.
- Determine if the needs of all road users have been adequately and safely met.
- Explore emerging operational trends or safety issues at that location.

Traditional safety reviews are reactive in nature and mainly identify safety issues after an unusually high number of crashes have occurred along a roadway or intersection. Table 2.1 details the differences between a RSA and a traditional safety review. The RSA process is much more formal than the traditional safety review.

The RSA process used by the FHWA is shown in Figure 2.1. To get a better understanding of the whole process each step is described in more detail. Details about the eight steps of the process are provided in Figure 2.1 to provide clarity on the processes used by the Utah LTAP program.

Step 1: Identify project or existing road to be audited. The objective of this step is to identify the existing road to be audited and to set parameters for the RSA. There are

Table 2.1 Comparison of Road Safety Audits and Traditional Safety Reviews (FHWA 2006).

Road Safety Audit Reviews	**Traditional Safety Reviews**
Performed by a team independent of the project	The safety review team is usually not completely independent of the design team.
Performed by a multi-disciplinary team	Typically performed by a team with only design and/or safety expertise.
Considers all potential road users	Often concentrates on motorized traffic.
Accounting for road user capabilities and limitations is an essential element of an RSA	Safety Reviews do not normally consider human factor issues.
Always generates a formal RSA report	Often does not generate a formal report.
A formal response report is an essential element of an RSA	Often does not generate a formal response report.

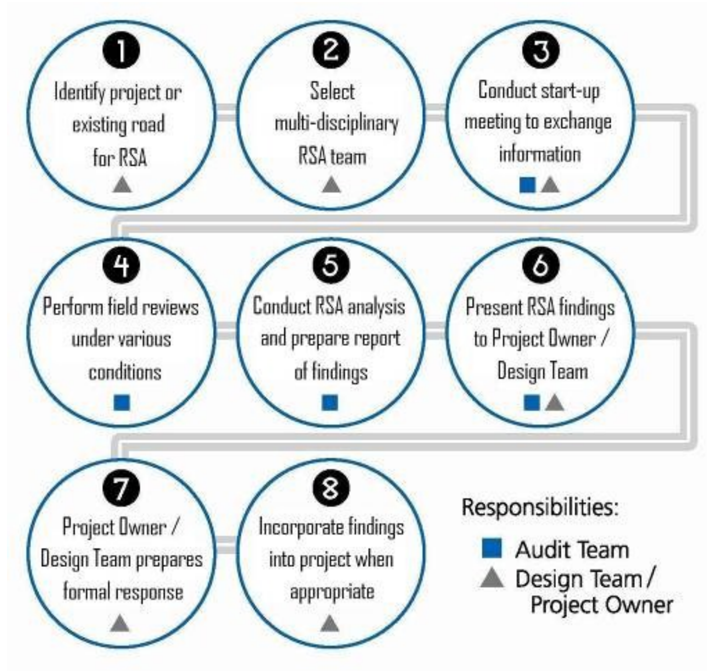

Figure 2.1 FHWA RSA Process (FHWA 2006).

many reasons that a road or intersection can be audited and they could include: roadway sections where there are general safety concerns, sections with high crash levels, high traffic volumes, geometric roadway and associated design issues, sections scheduled for overlay projects and school zones that have dangerous aspects associated with them. Once a roadway or intersection is selected, parameters need to be set that will define for the client what work will be accomplished. The parameters should define the scope, schedule for completion, team requirements, audit tasks, formal audit report contents and format, and response report expectations.

<u>Step 2: Select an RSA Team.</u> The client or project owner should select the RSA team leader and together they should select the remaining individuals that will be on the RSA team. The RSA team should possess a set of skills that will ensure the most critical

aspects of the project are addressed. The RSA team could include individuals with expertise in traffic engineering, design, maintenance, and safety engineering, as well as expertise in pedestrians and bicyclists, young and older pedestrians, older drivers, local knowledge, human factors, law enforcement, project scoping and representatives from local and federal governments. The ideal RSA team is the smallest team that brings all of the necessary knowledge and experience to the process. Individuals from within the agency can be very instrumental in firsthand knowledge and can add to the overall knowledge of the project being audited but must be impartial to the project and must act independent of the agency they work for. The freedom and ability of auditors to comment frankly on potentially controversial safety issues is crucial to the success of the RSA.

Step 3: Conduct a Pre-audit Meeting to Review Project Information and Drawings. The pre-audit meeting should provide all team members with an overview of the process the team is undertaking. The project owner will then need to provide all relevant information about the project being audited. These could include: road function, classification, environment, traffic and environmental characteristics of the road and adjacent road network, crash data detailing the location, and aerial photographs. Other usual information if available could include residents' complaints, police observations, bicycle and pedestrian use, and any school zones on the project.

Step 4: Review of Project Data and Conduct a Field Review. This is the most important step in the RSA process and the field reviews should see the project at least two different times of day. Usually the team will walk through the segment together and note anything that will affect the safety of the road. Standards and policies can be a starting point but compliance with standards does not necessarily result in a safer roadway. Photos and video should be taken of all issues to help in writing the final RSA report. The RSA team should look at physical evidence of past crashes and off-road excursions which could include:

- Damage to curbs, roadside barriers, trees, utility poles, delineator posts, and signs.
- Scuff marks on curbs and concrete barriers.
- Skid marks, broken glass, oil patches on the road.
- Vehicle tracks or rutting in the ground adjacent to a roadway.

Step 5: Conduct Audit Analysis and Prepare Report of Findings. This step the RSA team will finalize the RSA findings and develop suggestion in mitigating them. Additionally the audit team should establish how they wish to evaluate risk from certain features and how to prioritize the suggestions given. Figure 2.2 shows the components that each RSA should include.

[redacted]

Figure 2.2 Outline of an RSA Report (FHWA 2006).

Step 6: Present Audit Findings to Project Owner/Design Team. One important aspect of this step is to share with the project owner the key findings and suggestions identified in the RSA report and see if they fit in with the project goals. The team leader needs to remind the owner that the intent of the RSA was to identify opportunities to improve safety and it is not a critique of the road. It is also important to gather additional information from the owner about safety recommendations at specific areas. This will allow the RSA team to look back at the project and to modify any recommendations.

Step 7: Prepare Formal Response. This is the requirement of the project owner to explain what RSA recommendations are going to be implemented and what are not going to be. Some considerations can be:

- Is the RSA report finding within the scope of the project?
- Would the suggestion made in the RSA report address the safety issue?
- Will the suggestion made in the RSA report lead to mobility, environmental, or other non-safety related problems?

- What would be the cost associated with implementing the suggestions? Are there more cost-effective alternatives that would be equally effective?

Step 8: Incorporate Findings into the Project When Appropriate. This step is to implement the safety recommendations found in the RSA report and to ensure the RSA process was a learning experience. The project owner will need to ensure that the agreements described in the response report are completed as described and in the time frame documented.

2.5 Practice of RSA's

In 2004, NCHRP released a synthesis 336 on the current practices of RSA's and RSAR locally and international (Wilson and Lipinski 2004). It includes a comprehensive literature review, a survey of state and provincial departments of transportation (DOTs) by using a structured questionnaire, and the authors' personal contacts and experiences in providing RSA team leadership and training worldwide. This document will provide the majority of material for this section (Wilson and Lipinski 2004).

2.5.1 International Practice of RSA's

The experiences in Europe and Australia have shown that RSA's are both effective and cost beneficial as a proactive safety improvement tool. Studies have shown in the United Kingdom that the average number of fatal and injury crashes at 19 project sites that were audited fell by 1.25 crashes per year while crashes at 19 comparable non-audited sites dropped 0.26 crashes per year (Wilson and Lipinski 2004).

The majority of the content reviewed in the synthesis 336 was based on an international conference sponsored by the United Kingdom's Institute of Highways and

Transportation held in London in October 2003. The conference provided an opportunity for RSA practitioners to share experiences with RSA's.

The United Kingdom started use of RSA practices in the 1980s and have since then become the leading experts in the field. It is now mandatory to conduct a RSA for all trunk roads and highway improvement projects. In addition, it is also mandatory to conduct an RSA monitoring process of all projects that have involved an RSA in the past. The monitoring process takes place after 12 and 36 months to determine the benefits of the RSA. There are three stages of audits required separately or in combination for improvement projects. The required U.K. audit stages are:

1. Completion of the preliminary design.
2. Completion of the detailed design.
3. Completion of construction (in the United States, referred to as an RSAR).

After the site visit the RSA team submits the RSA report in a draft form so any issues agreed to be outside of the scope of the project can be removed. Only issues relevant to safety should be included in the RSA report. The RSA report is separated into 10 items.

1. Brief project description;
2. Audit stage team members and other members;
3. Site details, who was present, and conditions of weather and traffic on day of the site visit;
4. Specific road safety problems identified, with sup-porting documentation;
5. Recommended actions for removal and mitigation;

6. Location maps marked and referenced to problems;
7. Statement signed by the audit team leader, in a required format;
8. List of documents and diagrams considered for the audit;
9. Separate statement for each identified problem de-scribing the location, nature, and types of accidents likely to be considered as a result of the problem; and
10. Associated recommendations (checklists are not to be included) (Wilson and Lipinski 2004).

Australia and New Zealand began using RSA's in 1990 following exchanges and visits by road safety engineers from the United Kingdom. RSA's were first introduced on existing roads as well as on design projects. RSA's are now recommended in the national road safety strategies for both countries. In Tasmania, the city of Clarence recently had all its existing roads audited. In Western Australia, Australia, the creation of a road safety audit panel involving state, local government, and consulting practitioners had a positive effect on the adoption of road safety audits in that state. One of the main focuses for the use of RSA's is on training and a road safety auditor needs to have the following requirements:

- Have a minimum of five years of experience in road design, traffic engineering, or a closely related road safety discipline;
- Have successfully completed a training course approved and recognized by the state road authority.
- Certify that he or she has maintained current knowledge and experience in road safety auditing.

Checklists have been used more extensively and are more detailed compared to those of the United Kingdom. There is a risk that inexperienced practitioners might regard an audit as a process of "checking off the checklist." It has been found that less experienced auditors tend to audit against standards more than experienced auditors.

2.5.2 U.S. Practice of RSA's

The usage of RSA's have been steadily increasing as DOTs and other agencies discover the benefit of conducting RSA's on their roadways. Figure 2.3 shows how many states have been involved with RSA's and Texas is the only state that has had no RSA's conducted. Sixteen states have RSA programs running and 26 states have piloted or performed RSA's. Five states have been active in the RSAR's and they will be covered in more detail.

Pennsylvania was one of the first states to implement RSA's into their safety programs in the U.S. They began a pilot program in 1997 and particular attention was paid to developing a process that differentiated the audit process from safety reviews. Their RSA teams included five people from six disciplines areas: traffic engineer (coordinator), construction services, project design, highway safety maintenance, risk management, and comprehensive safety (human factors). All were in-house, except for the human factors person. The main safety issues identified were the need for left-turn lanes, day lighting of intersections, presence of fixed objects, roadway realignment, lengths of acceleration and deceleration lanes, pedestrian needs, and sight distance. The estimated costs of the audits ranged from $2,000 to $5,000. After the pilot study was

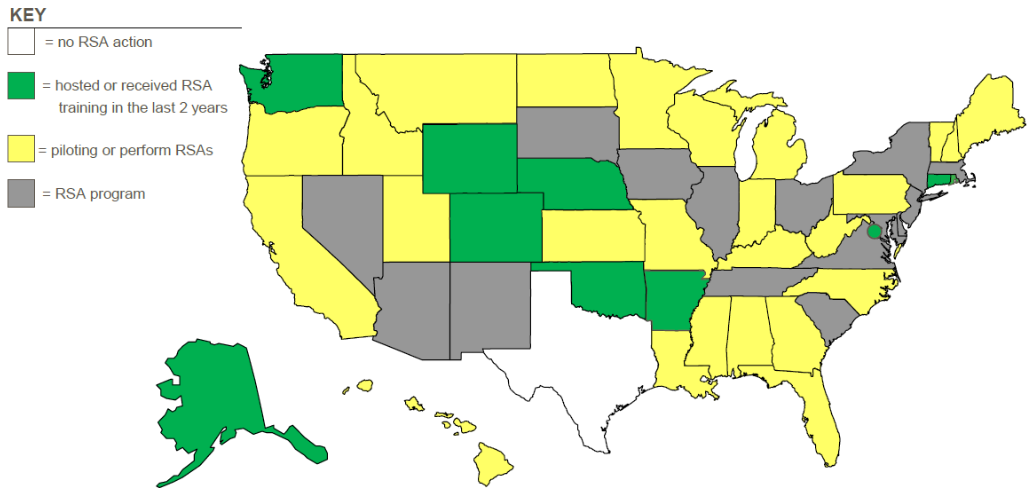

Figure 2.3 Current use of RSA's in the US (Crowe 2009).

completed a set of recommendations were developed that included:

- Get buy-in at all levels early in the process,
- Establish a coordinator's position,
- Select an audit team that is interdisciplinary and has the required expertise,
- Provide training to team members,
- Separate the audit process from safety reviews,
- Conduct the audits early in the design process,
- Cite audit safety concerns and not provide recommendations, and
- Ensure that the process involves multiple opportunities for communication. (Wilson and Lipinski 2004)

The South Carolina RSA program is administered by their DOT safety office and their RSA coordinator handles the day to day operations. They also have a committee that approves operating procedures and selects the projects to be audited. Projects include Interstate projects, rural and urban system upgrades, and innovative projects listed in the State Transportation Improvement Plan (STIP) pertaining to existing roads. (Wilson and Lipinski 2004)

A review of past RSA case studies conducted in South Carolina has been widely documented by FHWA. In the South Carolina 50 road safety audits of existing roads and six road safety audits for design projects were completed. On Interstate 585 in Spartanburg County, eight recommendations were made and four implemented on the freeway. SCDOT realized a 12.5 percent decrease in crashes and a $40,000 savings. On state route 296 in Spartanburg, 25 of 37 recommendations were implemented leading to a 23.4 percent reduction in crashes with an economic impact savings of $147,000. On state route 14 in Greenville, 9 recommendations were implemented with a 50 percent reduction in fatalities and cost savings of $3.66 million (Wilson and Lipinski 2004).

New York was one of the first states to implement RSARs on their local road systems. During the first year of the New York program, 216 safety treatment sites were identified, and 107 safety improvements were implemented. The initial estimates of the cost of the program was that the cost would be $15 to 25 million dollars per year and there would be 1,000 fewer crashes resulting in savings of $25 to 50 million dollars per year in productivity and other costs. The researchers found that the estimated savings were conservative. Crash reductions ranged from 20% to 40% at a larger savings than initially estimated (FHWA 2009b). RSA's are mandatory on all resurfacing projects because it was found in that simple resurfacing without roadside improvements contributed to increases in the number of crashes in the 3 years following resurfacing. The program is part of the Safety Appurtenance Program (SAFETAP) and involves maintaining existing safety features and adding appropriate, implemental, low-cost safety features at preventive maintenance project locations.

The SAFETAP initiative includes the following elements:

- Team of auditors with the expertise to assess existing and potential crash problems.
- Review of existing crash data and a site inspection.
- Recommendations of cost-effective solutions by the audit team to agency leaders with the responsibility for implementing crash countermeasures.
- Reports to the Traffic Engineering and Highway Safety Division describing the disposition of recommendations and implemented actions.

Iowa is similar to New York in that Audits are conducted in conjunction with corridors scheduled for resurfacing. The Office of Traffic and Safety administers the program and the state safety engineer is the RSA program director. The typical RSA team consists of safety personnel from the DOT and FHWA as well as personal from maintenance and construction staffs. Local law enforcement were asked for their input on the road being audited but were not part of the RSA team. Some of the safety deficiencies and recommendations include:

- Substandard curves—add or correct super elevation, add pavement, remove fixed objects, delineate curves, pave shoulders, install shoulder rumble strips, and use larger or brighter chevrons.
- Safety dikes (escape ramps)—install opposite “T” intersections and remove fixed objects.

- Day lighting of intersections and driveways—cut vegetation, remove fixed objects, and flatten driveway cross slopes.
- Other intersection needs—add turn lanes and signal enhancements.
- Roadside features - add or undertake guardrails, culvert and inlet modifications, cattle crossings, tree removal, and improvements of cross slopes, and riprap; relocate and delineate utility poles.
- Other - install larger stop signs and center and shoulder rumble strips. (Wilson and Lipinski 2004)

2.5.3 Comparison of Other States RSA Programs

The road safety audit process in each state followed the basic plan set forth from the FHWA. Each state then came up with different implementations for the process. A review was conducted of the Road Safety Audit programs in Pennsylvania, Minnesota, and Iowa to help evaluate Utah's program. The biggest difference between Utah and the other states was the composition of the Road Safety Audit team. Each state had transportation engineers, safety engineers, and police officers. Utah was unique in that professionals in other areas of expertise were included in the team. This included street superintendents, mayors, local residents, principles and city council members. This is significant since the team is usually the source for all of the data and recommendations on the road.

Each state compiled common data such as crash history, traffic volumes, aerial photographs, existing programs, and any future developments. Some differences for Utah were the sign and feature inventory. Before the site visit the Utah LTAP Center created a sign inventory incorporated into the Safety Software Suite that recorded all the sign conditions. Signs can be one of the most cost effective approaches to make a road or intersection safer. Having a sign inventory and a GIS map of the signs helped the RSA team save time to look at broader problems of the road.

The recommendations from the different states had many common safety improvement recommendations. The most common recommendation was adding additional signing on the road, improving sight distances, and removing hazardous objects in the right of way. Engineering, enforcement and education strategies were present in most final reports. One major difference for Utah was the focus on pedestrian and bicycle safety issues. Table 2.2 compares the different states Road Safety Audit programs.

State	RSA Team	Data Archiving	Recommendations
Utah	Safety Engineer, traffic engineer, UDOT representative, Local police department, education principles, street superintendents, city council members, city mayors, local residents	Crash history analyzed, signs inventoried, potential safety hazards inventoried, traffic volumes, aerial photography, video log, community member insight, pedestrian and bicycle data	Signing, striping, lighting, sight distances, on-street parking by schools, school routing plans, guardrail upgrades, pedestrian facilities, bicycle facilities, hazardous objects, pavement condition
Penn-sylvania	5 members - Traffic Engineer, Construction Services Engineer, Design Project Manager, Risk Management Engineer, comprehensive Safety Coordinator	Not Available	Intersection improvements: sight distance, lighting, left turn lanes; Hazardous fixed objects, Checklists
Minnesota	11 team members 10 members with engineering background and 1 retired state patrol officer	Crash summary, collision diagrams, Traffic Volume flow maps, Corridor Plan Sheets, Aerial photography, Video log, Still photographs, Mn/DOT staff knowledge of history and issues, field	Signing, striping, lighting, sight distances, Education, Enforcement, speed limit changes, Access Management implementation

Table 2.2 Comparison of RSA Practices in Other States.

		notes.	
Iowa	Police department, IDOT, safety consultants, FHWA representatives, professors	Crash history obtained, review of enforcement programs, crossing guard programs, traffic signal conditions, traffic volumes, Surface friction data	Geometric concerns, signing, striping, lighting, sight distance, install rumble strips, hazardous fixed objects, Enforcement strategies, Public education strategies.

2.6 Risk Rating Tools

Utah LTAP examined previous RSA implementations to develop a process that was used utilized in 18 RSARs conducted by Utah LTAP. The state of the art from the initial wave of FHWA conducted road safety audits were documented in a Technical Report from the FHWA titled *Tribal Road Safety Audits: Case Studies* (2008). The risk ratings that were found during these reviews were qualitative and based on the RSA teams view of the risk associated with each safety issue. Table 2.3 shows an example of safety issues with their risk rating and suggestions.

For each of the cited safety issues in Table 2.4 and the associated suggested improvements, a review was made of two recognized references that set forth accident reduction factors for various types of highway safety improvements. These references are a research report by the Kentucky Transportation Center entitled, “Development of Accident Reduction Factors – KTC 96 13” (Agent et al. 1996) and Report No. FHWA-SA-07-015 entitled, “Desktop Reference Manual for Crash Reduction Factors” (FHWA 2007). The crash reduction factors selected from these two references are shown in Table

2.4 for each of the cited safety issues and suggested improvements. The crash reduction percentage is the expected affect that the suggested improvement would have if implemented.

South Dakota State University developed a Rural Road Safety Index (RRSI) that quantifies the risk observed during a RSAR on a rural roadway. The RRSI looks at two indices, the estimated relative increase in accident probability, and the estimated relative increase in accident severity caused by the various safety issues. Table 2.5 was developed that looks at 5 different categories: Roadside Obstacles, Signs and Delineation, Cross Section, Alignment/Accesses and Road Surface/Maintenance. For each category questions are asked that quantify the risk that each safety issue poses to the roadway.

Each safety question is graded on a scale of 1 to 4, where 4 being the best grade

Table 2.3 Summary of Selected Safety Issues and Suggestions (FHWA 2008).

SAFETY ISSUE (Number and Description)		RISK RATING	SUGGESTIONS
1	*Signing and Pavement Marking:* Worn or missing signs and pavement markings may limit driver guidance, especially at night.	D	• policy measures • measures to improve visibility and reduce maintenance requirements
2	*Pedestrian Facilities:* The design and maintenance of some pedestrian facilities may limit their usefulness. Pedestrians who are unable or unwilling to use pedestrian facilities may use the roadway instead, where they are exposed to vehicle traffic.	D	• maintenance schedule review • completion of pedestrian networks with sidewalk segments and marked crosswalks (where currently missing) • removal of obstructions in sidewalk
3	*Poor Pavement Conditions:* Cracked, worn, rutted, and dusty/muddy pavement may reduce driver control (especially for motorcyclists), particularly on N-12 between N-110 and Hwy 264.	C	• pavement repair and rehabilitation
4	*Intersection of N-12 and N-100 (Window Rock):* • Peak period left-turn volumes exceed the capacity of the left turn lanes. • Access to the residential area interferes with operations at the N-12/N-100 intersection. • Fixed-object hazards are located in the right-turn channelizing island. • Laning on the east exit leg is not clear.	C	• extend left turn lane to accommodate peak demand • revise signal operation to clear queue • introduce staggered work hours to reduce peak volumes • reconfigure intersection to four legs • relocate signal controller box • clarify laning requirements on eastbound exit leg

Risk Rating:	A: lowest risk level	C: moderate-low risk level	E: high risk level
	B: low risk level	D: moderate-high risk level	F: highest risk level

that requires no treatments. A survey was conducted to determine the weight of each category with roadside obstacles and road surface/maintenance determined to have the greatest risk for roadway safety. The final score is determined by deducting the sum of all of the categories from 100 (Mahgoub et al. 2010).

The Wyoming Local Technical Assistant Program developed the Wyoming Rural Road Safety Program (WRRSP) that analyzed crash data as well as roadway safety risk seen during a RSAR (Ksaibati et al. 2009). The WRRSP is a five-step procedure that identifies high risk locations and applies safety countermeasures based on a benefit cost analysis. These five steps are:

1. Crash data analysis

Table 2.4 General Safety Issues and Recommendations.

Cited Safety Issues (Description)	**Recommended Improvement**	**Crash Reduction**
Outdated and faded signs	Upgrade signs to new MUTCD requirements and post assemblies.	15%
Faded pavement markings	Repaint pavement markings.	15%
Improve Sight Triangle	Trim trees & remove elements blocking sight	23%
Clear zone concern	Remove large landscaping rocks to improve clear zone safety	23%
Sidewalk & ADA provisions	Update ADA provisions and transition plan	20%
Limited provisions for bicycles	Evaluate potential for adding bike lanes	20%

Table 2.5 Rural Road Safety Index Table (Mahgoub et al. 2010).

	Safety Issues		**Deduct Points**
	Roadside Obstacles		30 Points
Rank 1	Rigid utility poles, Rigid obstacles, Inadequate bridge rails	≥ 5 times.	30
Rank 2	Rigid utility poles, Rigid obstacles, Inadequate bridge rails	≥ 3 times.	20
Rank 3	Rigid utility poles, Rigid obstacles, Inadequate bridge rails	≥ 1 time.	10
Rank 4	4. No Roadside obstacles within the whole section.		0
	Signs and Delineation		10 Points
Rank 1	Curve warning missing or ineffective on severe curve.		10
Rank 2	Guideposts or barrier reflectors damaged or missing.		7
Rank 3	Some Curve warning missing or inadequate.		5
Rank 4	No deficiencies on roadside signing.		0
	Cross Section		20 Points
Rank 1	LW< 9 ft. / No shoulder.		20
Rank 2	9 ft. < LW ≤ 10 ft /No shoulder.		15
Rank 3	9 ft. < LW ≤ 10 ft. /Sufficient shoulder		10
Rank 4	LW > 10 ft / Sufficient shoulder.		0
	Alignment and Accesses		30 Points
Rank 1	Sight distance problems present	≥ 5 times.	30
Rank 2	Sight distance problems present	≥ 3 times.	20
Rank 3	Sight distance problems	≥ 1 time.	10
Rank 4	No sight distance problems within the whole section.		0
	Road Surface and Maintenance		10 Points
Rank 1	Very poor surface & maintenance, corrugation and pot holes...		10
Rank 2	Presence of corrugation, pounding, holes…		7
Rank 3	Slightly deteriorated roads.		5
Rank 4	Good and very good surface		0

2. Level I field evaluation
3. Combined ranking to identify potential high risk locations based on steps 1 and 2
4. Level II field evaluation to identify countermeasures
5. Benefit/cost analysis

There are five categories used in the Level I field evaluation. The road should be evaluated in the field and analyzed for each one-mile segment. Each one-mile section will be given a rated score of 0 to 10 for five categories, with 0 being the worst and 10 being the best. The five categories are:

1. General
2. Intersection and Rail Road Crossings
3. Signage and Pavement Markings
4. Fixed Objects and Clear Zones
5. Shoulder and ROW.

In order to select the roadways to be included in the Level II field evaluation, a combined ranking is obtained based on the total crashes ranking and the rankings from the Level I field evaluation. In step 1, road segments were ranked based on the total number of crashes. Road segments' field scores obtained from Step 2 should be also used to rank the sections. Lower field scores should result in lower field rank. To obtain the combined rankings, the crash and Level I rankings for each segment are added. The top 15 segments with the combined smallest numbers are considered the most hazardous and included in the Level II field evaluation. Combined rankings based on crash data and field evaluations are used to identify segments with the highest potential crash risks. A comprehensive analysis is then conducted on each high-risk segment. The objective of this evaluation is to identify low-cost safety countermeasures for segments identified as high-risk locations.

Level II field evaluations are performed on roadways, which are identified as high-risk locations based on the combined score from the crash analysis and the Level I field evaluation. At this point, traffic volumes and speeds are collected on the selected roads for seven days. In addition to the traffic information, important specific information should be collected on the geometric features of the road, safety concerns, signs and pavement markings. Below is some of the information that should be collected in the Level II field evaluation, which is similar in nature to road safety audits. It should be mentioned here that crashes should be evaluated to determine the top three causes of crashes on each section prior to conducting the Level II field evaluation. The following items should be considered in this evaluation:

- Horizontal curvature measurements
- Horizontal and vertical stopping sight distances
- Steep slopes
- Intersections
- Signs, pavement marking, and delineators
- Fencing
- Fixed objects in ROW
- Bridges
- Cattle guards

- Shoulders

2.7 Conclusions

This chapter presented how RSA's are used and the benefits that can be gained through them. Additionally it showed how RSA's are proactive in nature and the tools needed to quantify risks identified in RSA projects. The major conclusions that are drawn from the literature review are shown below:

- RSA's are proactive in nature and are focused on identifying safety risks before they result in crashes.
- The benefits gained through other RSA programs.
- Major differences between Utah's RSA program and others.
- Provided a review of the literature that was used in developing the RSA risk assessment tool.

The next chapter will describe Utah's RSA pilot program and the 18 RSA projects that were performed. Also it will highlight the lessons learned and any successes that were realized through the RSA pilot program.

CHAPTER 3

UTAH'S ROAD SAFETY AUDIT PROGRAM

All RSA's teams were organized and the field reviews were conducted for the eighteen candidate local road segments submitted by Utah local agencies. The field reviews included all the preliminary work, the field observations, the submittal of RSA reports and follow up actions taken by the local agencies and Utah DOT in response to the individual RSA Reports. In addition, each local agency was introduced to the Safety Software Suite (Crash Analysis Program, Sign Management Program, Intersection Analysis Tool, & RSA Tool) and assistance given in the implementation of the Safety Software Suite as requested.

Table 3.1 contains a listing and description of the 18 RSA's that were conducted in the RSA program. Preliminary field inventory and GPS/GIS mapping of all the candidate road segments were conducted including the development of DVD's of each road segment as seen from a driver's perspective. Inventory was made of all road features, traffic control devices, and potential safety hazards. This inventory information along with GIS photo logs was provided as appendices in each RSA Report. These photo logs were prepared to assist local agencies and Utah DOT in the implementation of the suggested safety improvements. This preliminary information assisted the multi-disciplinary RSA teams' field assessment of actual conditions. The GPS-based inventory tool that was added to the RSA module to facilitate inventory and identification of potential roadside hazards and physical features of the road was very useful in collecting this information and including it in the individual RSA reports.

Table 3.1 Road/Street Segments Selected for the Road Safety Audits.

Local Agency	**Description of Candidate Road Segment**
Francis Town	Intersection of Hilltop Road and State Road 32
Centerville	Frontage Road along the east side of I-15 in Centerville from Pages Lane on the south to Glover's Lane in Farmington on the north, a distance of about 4 miles
Monticello	Ten blocks-From Main Street west to 200 West, then south for four blocks with one crossing of Center street. At the High School, from 200 West and 200 South, continuing east on 200 South back to Main Street
Hurricane	Section of 1100 West between 700 West and 3000 South
Salt Lake City	Segment of 1300 East from South Temple to 2100 South in Salt Lake City.
Enoch City	Intersection of Valley Road & Minersville Road
South Weber City	State Road 60 (South Weber Drive) 3 miles of narrow winding road
Grand County	Intersection of 500 West and Kane Creek Blvd. in Moab City.
Salt Lake County	Intersection of 2000 East and Siggard Drive (3650 S.)
Weber County	1200 S. from 4700 W. to 5900 W.
Box Elder County	Road 1: Iowa String Road (6800 W), from 10400 N to Hwy 83. (8.8 miles) Road 2: 6800 N. (Landfill Road), from Iowa String Road intersection to landfill. (5.7 miles)
Pleasant Grove	North Section of roadway that is SR 146 (100 East) from U.S. Hwy. 89 to 2600 North
Uintah County	Curve at 17500 East 2250 South on the Ft. Duschesne – Randlett Hwy.
Carbon County	Lower Miller Creek Road (2.8 miles) & Old Wellington Road (3.8 miles)
Iron County	Triple Road & Kanarra Road
Juab County	Old Hwy. 91 starting at north end of County line running two miles including new subdivision & school zones around Rocky Ridge Road.
Layton City	Intersection of Church Street and Fairfield Road
San Juan County	Intersection of county and state road.

The 18 RSAR reviews covered a large spectrum of functional road/street facilities. They included arterial roads, collector roads, state highway roads, county and city local roads/streets, roads serving tribal agencies, and seasonal/recreational roads. Conduct of RSA's of such a broad spectrum of road facilities shows the utility and safety benefits of applying RSA concepts and procedures to all types of facilities.

The following activities were completed for the conduct of each RSA:

1. Collected, compiled and evaluated crash history of each selected road segment.
2. Inventoried road/street segment geometrics, traffic control elements, traffic information, and develop GIS map for the features.

3. Conducted preliminary field review of potential safety hazards.
4. Contacted potential RSA team members and established field RSA teams (i.e., team leader, traffic engineer, risk manager, FHWA safety engineer, UDOT traffic safety representative, local resident representative, law enforcement).
5. Conducted web conference with RSA team members to organize and outline RSA activities and responsibilities.
6. Scheduled field RSA's.
7. Conducted field RSA reviews.
8. Compiled RSA team comments and recommendations.
9. Draft RSA Reports were completed and sent to local agencies for comment and follow up action.
10. Follow-up was made with each local agency and Utah DOT to review and reconcile any comments and suggestions that were made in the draft RSA reports.
11. Revisions were made where necessary in the RSA reports and the reports finalized including the comments and actions taken by local agencies in response to the RSA reports.

Prior to starting the inventory work, a video was taken of each segment to show a driver's perspective of the street in both driving directions. Then, crash data and crash history information was acquired from UDOT and the local police departments. The crash data was compiled and incorporated into the Safety Software Suite. The Safety Software Suite Crash Analysis module visualizes crash densities on a GIS map and associates crash statistics such as crash types and injuries types in graphs.

Physical inventories, measurements, attributes of the street geometrics, physical features (trees, curb and gutters, access points, utilities, etc.), intersections, traffic signs, pavement markings, and signal systems along with identification of potential safety hazards were made and incorporated into the safety software suite feature module. These maps and associated information were provided to the RSA team members to aid in their review. Table 3.2 details the preliminary data collected for the RSA's.

Table 3.2 Road Safety Audit Preliminary Data Collected.

LOCAL AGENCY	Preliminary Data Collected
Centerville	Road Features, Signs, Crash Data, Intersections, Video.
Francis Town	Road Features, Signs, Intersection, Video
Hurricane	Road Features, Signs, Crash Data, Intersections, Video
Monticello	Road Features, Signs, Crash Data, Intersections, Video
Pleasant Grove	Road Features, Signs, Crash Data, Intersections, Video
Salt Lake City	Road Features, Signs, Crash Data, Intersections, Video
South Weber City	Road Features, Signs, Crash Data, Intersections, Video
Enoch City	Road Features, Signs, Crash Data, Intersection, Video
Layton City	Road Features, Signs, Crash Data, Intersection,
Grand County	Road Features, Signs, Intersections, Video
Salt Lake County	Road Features, Signs, Crash Data, Intersection, Video
Weber County	Road Features, Signs, Crash Data, Intersections, Video
Box Elder County	Road Features, Signs, Crash Data, Intersections, Video
Uintah County	Road Features, Signs, Crash Data, Traffic Counts, Video
Carbon County	Road Features, Signs, Crash Data, Intersections, Video
Juab County	Road Features, Signs, Crash Data, Intersections, Video
Iron County	Road Features, Signs, Intersections, Video
San Juan County	Road Features, Signs, Crash Data, Intersection

3.1 RSA Team Selection

The RSA team was usually made up of a team leader, FHWA safety engineer, UDOT representative, local resident representative, local political representative, law enforcement. The number of teammates in the RSA teams ranged from 3 to 11 and averaged around 8 members. The major difference from other states RSA's teams was

Utah's teams were usually half comprised of local representatives. It was instrumental in connecting the city council members with the engineering department and police department so they all could get out on the road to come up with solutions together. Working with different departments made it easier to get the necessary background, which enabled the team to make plausible recommendations. An added benefit was the chance to teach the local government of how to make their other roads safer through low cost solutions so they could apply the same techniques to their other roads.

3.2 RSA Site Visit

Each RSA site visit began with a meeting to associate all of the team members what is expected out of a RSA. Since it was the majority of team members first time auditing a road the meeting required some prior training to learn what a road safety audit entailed. The next step in the meeting was to go over all the information about the road. The local representatives were relied on to get a better understanding of the demographics of the road. The items discussed included any future improvements to the road, jurisdictional issues, new developments, operational issues, and firsthand knowledge of the road from the police department. The local representatives also helped the RSA team know how many pedestrians usually used the road and the condition of the pedestrian facilities. An example is in the South Weber City preliminary meeting the city officials brought to the team's attention that bicycle clubs were using the road as a main route. This was causing cars to pass the platoon of bicycles on a narrow road with little sight distance. This was noted during the RSA team visit.

Each team member was given a GIS booklet created from the safety software suite. Each booklet had the GPS location of all signs and features collected during the preliminary RSA inventory activities. During each RSA site visit, notes and pictures were taken of all comments mentioned by the RSA team to document all recommendations during the site visit. The RSA team concluded the site visit with a discussion of the major safety recommendations that needed to be addressed.

After the site visit was concluded the Utah LTAP Center compiled all data and notes together to finish a final report for the client. A low cost treatment for the majority of roads was sign and pavement marking upgrades. Some other common issues included inadequate sight distance triangles, clear zone issues, ADA provisions, and limited bicycle facilities.

3.3 Salt Lake City Experience

The Salt Lake City Transportation Division submitted a segment of 1300 East for a RSAR. The road was recently transferred from UDOT control to the city for operations. In this process, Salt Lake City was then given funds from UDOT to help make the road safer and more efficient.

The site studied for the road safety audit is located in eastern Salt Lake City. The segment is a north-south minor arterial from South Temple St. on the North to 2100 South. The roadway segment studied for the road safety audit was about 3 miles in length. The street is classified as an urban minor arterial serving resident and largely inbound commuter traffic. The street traverses older residential neighborhoods, small businesses and restaurants, high school zones, and provides principal accesses to the

University of Utah and Westminster College. The street intersects other minor arterial streets, major collectors, and local streets along with serving major Utah Transit Authority (UTA) bus routes. The street also intersects the UTA Trax Light Rail Route at 500 South. The street segment from South Temple to 2100 South varies in cross section from four traffic lanes with turning bays to two traffic lanes and then to three traffic lanes with a two-way turning lane as it intersects with 2100 South. Traffic volumes vary throughout the segment from a low of 12,000 vehicles per day (VPD) to a high of 26,000 VPD.

The transfer from UDOT to the City presented some inconsistencies relating to standard traffic control signage and pavement markings. With the education facilities and residential areas associated with the road, the citizens and the Salt Lake City government wanted to incorporate enhanced bicycle facilities and were striving to make the corridor more pedestrian friendly. The mixed-use attributes of the corridor made provided difficulties to the implementation of road safety enhancements for pedestrian and bicyclists while keeping the efficiency to motorized road users.

3.3.1 Data Collected

Prior to the audit, data was collected on 1300 East to assist the team members in the road safety audit process. First, video was taken of 1300 East to show a driver's perspective of the street in both the northbound and southbound directions. Second, a sign inventory was conducted by recording a GPS point at each sign location to correspond with a location ID. The sign inventory was then put into a database and displayed in the Utah Safety Software Suite. The information entered into the database included:

- Sign Condition
- Type of Sign (by MUTCD designation)
- Type of Sheeting
- Sign Dimensions (Width x Height)
- Sign Height (from the crest of the road)
- Offset from the Edge of the Road

The Safety Software Suite then provided a map that allowed the team to visualize the location of each sign in the corridor as shown in Figure 3.1 in a GIS corridor map. The suite also allowed the team easy access to the database with the attributes of all signs inventoried, as shown in Table 3.3. Third, features were collected by recording a GPS location at areas that had importance to the roadway. Features that were collected included road characteristics, road width change, speed limit change, location of crosswalks, utility line, sidewalks, road deficiencies, bus stops, and many other features that had importance to the street segment.

Crash data and crash history information was acquired from UDOT and the Salt Lake City Transportation Division. The UDOT data were compiled and incorporated in the Safety Software Suite Crash Analysis module and a GIS map was created showing the crash densities, crash types, and associated percentages of property damages and injuries**.** The Safety Software Suite provided the density and location of all reported

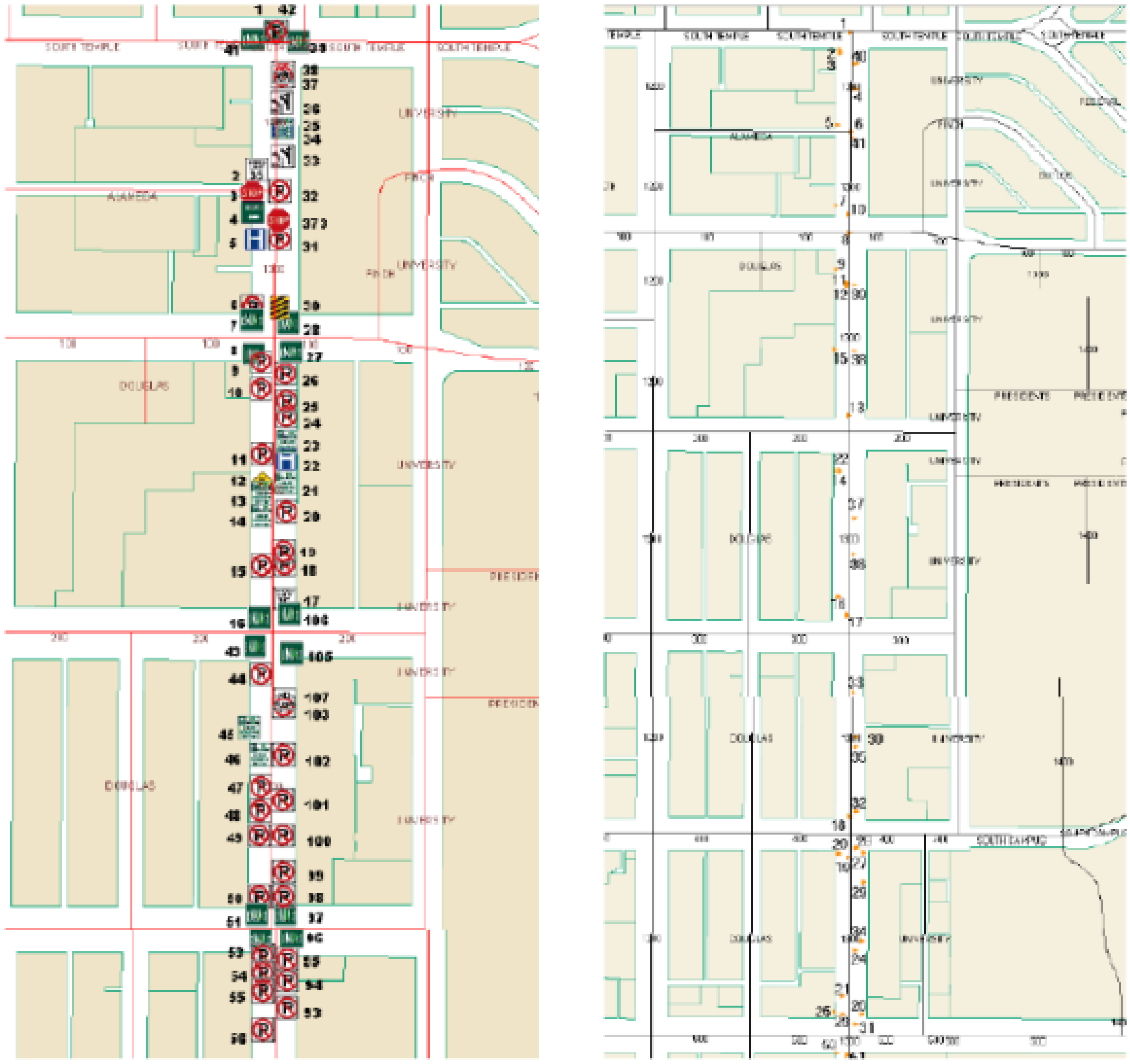

Figure 3.1 Sign and Feature Inventory Maps.

crashes that had occurred along 1300 East in a GIS format to the audit team. In addition, the types of collisions and the pattern of injuries that were sustained are shown in a pie chart format to display the percentage of each type of crash and the percentage of injuries and fatalities. Figure 3.2 shows density grid created from all of the crashes on 1300 East from 2001 to 2006.

The initial review that was conducted in conjunction with the RSA training course used four multi-disciplinary teams comprised of local agency public works personnel, law enforcement representatives, Utah Highway Safety Office staff, and a FHWA Traffic Safety Engineer. The formal RSA team was comprised of the following individuals from: the Utah Division of Federal Highway, the Salt Lake Transportation Division, UDOT, the Utah LTAP center and the Salt Lake City Police Department. The formal audit team consisted of 9 people.

In addition, contacts were made with additional representatives of the Salt Lake City Police Department, Public Works Division, and Engineering Division to gain their perspective on safety and operational issues on 1300 East. Since there was considerable concern expressed by local residents and community associations regarding pedestrian

Table 3.3 Sign Characteristics Table.

Support ID	Sign ID	Sign Condition	MUTCD	Sheeting	Sign Address	Sign Height	Offset	W X H
						feet	*feet*	*inches*
1	1	Good	D3-1	ASTM I	1297 East and S. Temple	18	13	36 X 12
1	2	Fair	R3-8	ASTM I	1297 East and S. Temple	7	13	30 X 30
2	3	Good	R2-135	ASTM I	48 South and 1300 E	7	2	24 X 31
32	55	Good	R7-108	ASTM I	48 South and 1300 E	6	2	12 X 18
36	62	Poor	R3-8	ASTM I	1 South and 1300 E	7	4	30 X 30
43	70	Good	D3-1	ASTM I	200 South and 1300 E	0	36	48 X 16
51	78	Good	D3-1	ASTM III	1299 East and 300 S	20	15	48 X 16
52	79	Good	D3-1	ASTM III	1299 East and 300 S	20	15	48 X 16
97	152	Poor	D3-1	ASTM III	299 South and 1300 E	16	16	48 X 16
102	159	Fair	R8-3A	ASTM I	200 South and 1300 E	5	5	12 X 18
106	164	Poor	D3-1	ASTM III	1300 East and 200 S	20	20	32 X 16

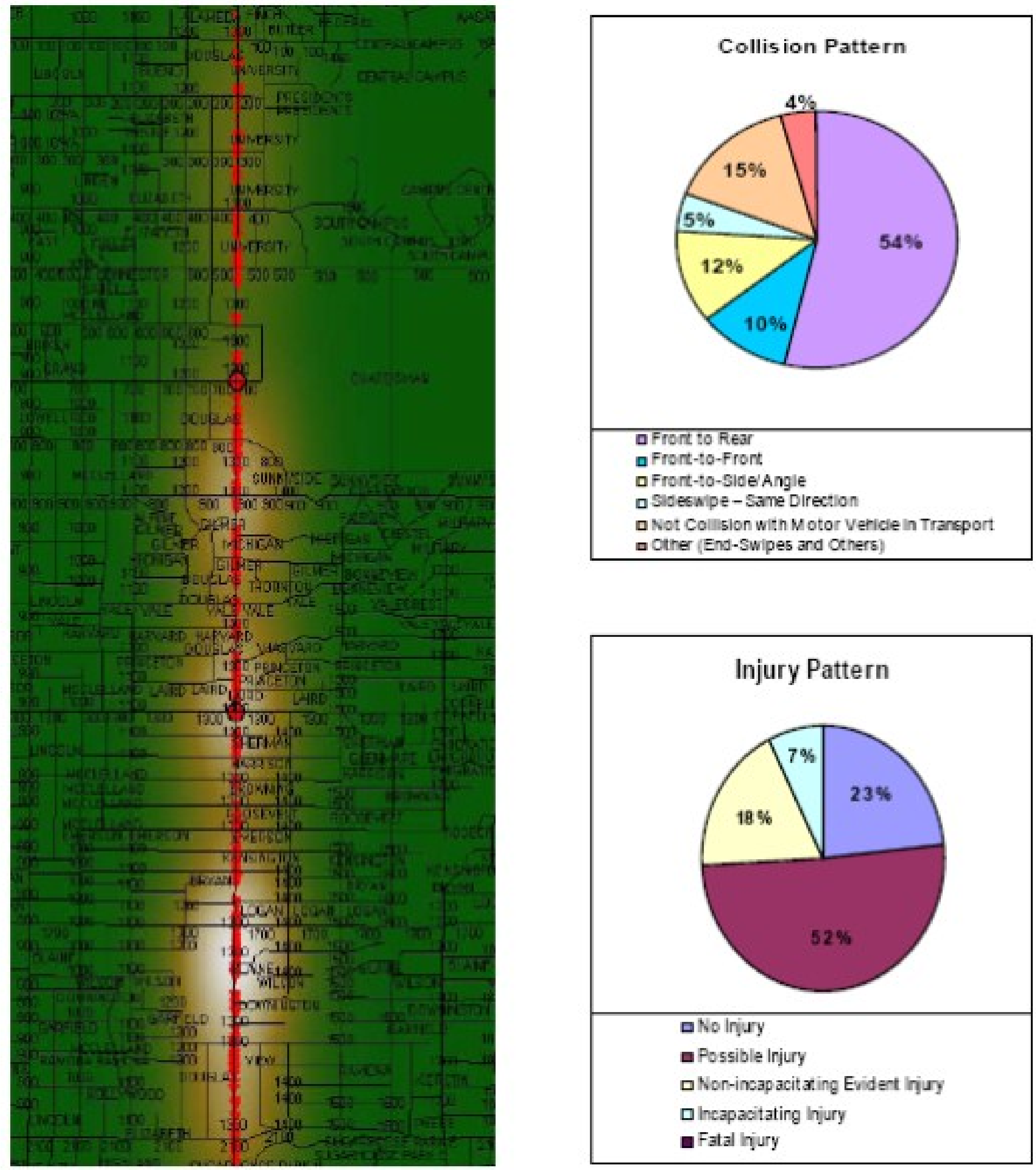

Figure 3.2 Crash Density Grid of 1300 East - 440 Total Crashes - UDOT Data.

and traffic safety along 1300 East, a special meeting was held with community representatives to register their concerns and to acquaint them with the objectives of the RSAR.

The RSA review teams agreed that the variable cross section that exists within 1300 East was a potentially dangerous feature of the roadway. The street begins with a four-lane travel section, which drops to two travel lanes before returning to a four-lane travel section. This requires vehicles to merge frequently. In addition, there are turn bays and areas were parking is allowed that further affect traffic flow and safety. Another common observation among the RSA teams was the deep (12 to 18 inches) gutter sections along both sides of 1300 East for significant lengths, which provided several hazards to motorized and non-motorized users of the roadway.

To mitigate the variable cross section, a road diet was suggested. Huang et al. concluded that road diets conversions of four-lane undivided roads into three lanes (two through lanes plus a center turn lane) are beneficial for safety improvements. In the road diet concept, the fourth lane may be converted to bicycle lanes, sidewalks, or on-street parking (Huang et al. 2002). Road diets help reduce conflict points and improve sight distances. The biggest benefit of a road diet is that pedestrians have fewer lanes to traverse when crossing the road and bicyclist gets the security of a designated lane. The main concern with the road diet concept in the corridor was that residents would lose on street parking. A visual plan of the road diet on 1300 East is shown in Figures 3.3 and 3.4.

There were many key findings concerning the following areas on the roadway. The concerns were in the following areas:

- Signage and Pavement Marking Upgrades:
- Gutters

- Pedestrian Count Down Signals
- Bicycle Accommodations
- Access Management
- Sidewalk and ADA provisions
- Transit Stop Locations
- Pedestrian Crossing
- Traffic Signal Conditions

The key findings and suggestions of the RSA are summarized in Table 3.4.

3.3.2 Implementation.

The last step in the road safety audit to incorporate findings is the most important since it is where the audit can actually impact the road safety. After the road safety audit team presented their final report the Salt Lake Transportation Division proposed five primary components and three secondary components to the upgrade of 1300 East.

The five main components include:

1. Conversion to a consistent three-lane street section.
2. Initial installation of pedestrian-activated flashing lights with conversion to HAWK signals at the marked crosswalk locations
3. Installation of bike lanes from 600 South to 1300 South
4. Reduction of the speed limit from 35 mph to 30 mph
5. Installation of three sets of driver speed feedback signs

The secondary components include:

1. The replacement of missing or poor condition signs

Figure 3.3 Use of the Road Diet Concept to Add Bike Lanes and Remove Parked Vehicle Obstacles (SLC Transportation 2010).

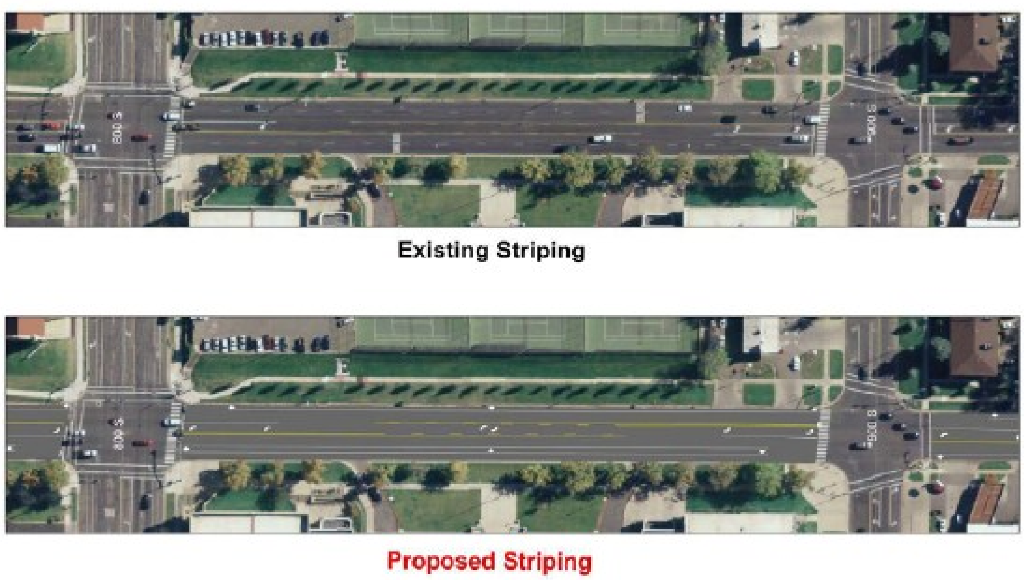

Figure 3.4 The Road Diet Concept That Allows for Parking on One Side of the Road (SLC Transportation 2010).

Table 3.4 Summary of Selected Safety Issues and Suggestions for SLC.

NO	Selected Safety Issues (Number & Description)	Risk Rating	Suggestions	Crash Reduction
1	Signage & Pavement Marking Upgrades: Retro-reflectivity Break away posts Pedestrian crossings Sign visibility blockage	C	Upgrade signs to new MUTCD requirements & post assemblies. Repaint pavement markings. Improve consistency in pedestrian crossing markings. Trim trees & remove elements blocking sign visibility.	30% 15% 25% 13%
2	Pavement Gutter Drop-offs were 12 to 18 inches.	B	Upgrade & improve driveway access bridges to residents.	25%
3	Alignment & proper functioning of Pedestrian Count Down Signals	C	Maintain & realign pedestrian signals.	24%
4	Limited provisions for bicycles	F	Evaluate potential for adding bike lanes	20%
5	Business accesses too close to intersections	D	Develop & initiate access management policy.	N/A
6	Sidewalk & ADA provisions	C	Reconstruct broken sidewalk Update ADA provisions	20%
7	Transit stop locations	E	Work with UTA to move transit stops to far side of intersections	1%
8	Variable street cross sections and variable number of lanes	D	Evaluate street cross section in conjunction with major street improvements.	25%
9	Pedestrian crossings & accessibility	C	Upgrade pedestrian crossing provisions	10%
10	Traffic Signal conditions	D	Upgrade signal heads	25%
11	Parking in narrow roadway areas	D	Eliminate parking in these areas	35%

Risk Rating: A: lowest risk level C: moderate-low risk level E: high risk level
B: low risk level D: moderate-high risk level F: highest risk level

2. The painting of stop bars on side streets
3. Addition of back plates on east/west signal heads

3.3.3 Public Input

While not usually in the guidelines for the road safety audit process, the audit team and the Salt Lake City transportation division felt that public involvement was very importation to the audit process. The Salt Lake City Transportation Division held an open house to present the findings and proposed improvements. It was important make the community aware of the changes that were going to be made and to inform them of the process that took place to implement the changes and the rationale that was used to make the decisions. In all, five presentations were given to various communities around the road being audited. One hundred thirty-eight comments were received, primarily from those living on or in the vicinity of 1300 East. The content of the comments ranged from total support for the proposed changes, to total opposition, and all combinations in between. Some of the comments were difficult to categorize because they were not always provided for each of the five main components of the proposed changes. In these cases, comments were ranked as either no comment, implied support, or implied against.

The majority of the comments regarding the proposed changes related to a conversion to a three-lane street section. Overall, the majority of those commenting (70-46) were against the change to a three-lane street section. The most common comments related to this opposition are in regards to the loss of parking and garbage pickup issues. Those in the 1700 South to 2100 South section were opposed to any change that would remove the existing three-lane street section in this area and did not provide any indication that garbage pickup or the current lack of on-street parking were issues. The majority of those living east of 1300 East were against a three-lane street section, with the major issue being concern about increased congestion and traffic being diverted into their neighborhoods. The majority of those living west of 1300 East supported a three-lane street section.

Comments regarding the installation of bike lanes from 600 South to 1300 South were mixed. The majority of comments were categorized as “no comment,” with support for the bike lanes getting the second highest number. There seemed to be some confusion regarding bike lanes because, while a number of those commenting support the installation of bike lanes from 600 South to 1300 South, they also were against the three-lane street section. One issue could be that residents did not understand that bike lanes and a four-lane section could not occur simultaneously.

A significant majority of the comments regarding the initial installation of pedestrian flashers with conversion to HAWK signals, the reduction of the speed limit, and the installation of three sets of driver speed feedback signs were in support or provided no specific comment about being in support or against these components. Those comments categorized as against these three proposed changes were generally due to the commenter indicating a general opposition to the overall proposal and not from indicating an opposition to any one individual component. After reviewing the public comments received, a second lane configuration option was considered for the 900 South to 1300 South section of 1300 East.

In order to gather more information from those who live and/or own property on this section of 1300 East, an additional survey and comment form was sent to residents following the public meetings. This survey asked the property owners and residents to provide their input on the original lane configuration option of a three lane section with a center turn lane, bike lanes, and no on-street parking, and the second lane configuration option one travel lane in each direction and full time parking. Over 80 surveys were sent out, and 38 responses returned. Thirty responses were received from those who are both property owners and residents, six responses were received from those who are property owners, and two responses were received from non-property owner residents. Overall, 74% of the responses were in favor of the three-lane section with a center turn lane and bike lanes. The public involvement processes provided valuable information to help decision makers implement the recommendations of the audit team.

3.3.4 Final Recommendation

The public input contributed significantly to refining the final recommendations. Based on the findings of the 1300 East Road Safety Audit, the public input comments received, and the overall review by the Transportation Division staff, the following is the approximate timeline residents saw the changes made along 1300 East in 2009, less than one year after the road safety audit:

- Pedestrian-activated flashing lights were installed at the existing marked crosswalk locations of Yale, Kensington, Wilson, and Downington, with future conversion to HAWK signals. The existing 700 South pedestrian-activated flashing light location also included a future conversion to a HAWK signal.
- Three sets of driver feedback signs were installed, with one set each in the 900 South to 1300 South, 1300 South to 1700 South, and 1700 South to 2100 South sections.
- The speed limit was reduced from 35 mph to 30 mph and the signal timing adjusted accordingly.
- 600 South to 1300 South: A three-lane section with center turn lane and bike lanes, which is consistent with the original proposal, was installed. Because 1300 East between 600 South and 800 South is wider than sections of the street to the

south, parking on the west side of 1300 East will also be included in this area. Parking on either side of 1300 East between 800 South and 900 South will not be included.

- 1300 South to 1700 South: The existing lane configuration, which consists of one travel lane in each direction and full time parking, will remain. This represents a change from the original proposal of a three-lane section and is primarily due to the input received from those living along this section of 1300 East. 93% of those living along this section who provided comments wanted the existing lane configuration to remain.
- 1700 South to 2100 South: The existing three-lane section, which is consistent with the original proposal, will remain.

3.3.5 Summary and Conclusions

The RSA process that was used was developed from the FHWA Road Safety Audit Guidelines. The Utah process deviated from the FHWA process by inventorying the all and signs and features to assist the audit team. Another addition to the process was that the Utah LTAP along with the Salt Lake Transportation Division held community meetings and engaged in a comprehensive public involvement campaign to better understand everyday users of the segment and make the residents and users of the roadway involved in the process. The diverse group of users and uses on the corridor demanded that the road safety audit process be more comprehensive. The traditional road safety audit team could not adequately represent the diverse needs of the population with the public involvement campaign. Multiple meetings were necessary with the Salt Lake City Transportation Department to complete the audit and the recommendation process.

The rapid implementation of the recommendations of the road safety audit team and report was one of the major successes of the project. The public involvement process informed the recommendations implemented. The residents and users of the roadway provided that there was a large consensus that the safety improvements implemented would be accepted. One of the drawbacks of this process is that the recommendations implemented are not the optimal for the corridor as recommended by the audit team. However, the parking concerns of the residents were valid and required that the recommendations to be implemented were not exactly the recommendations of the audit team.

The result of the safety audit was a much safer roadway than what existed before the audit. The ability to introduce a bike lane and the signalized crosswalks made a significant impact to the goal of making roads more pedestrian and bicycle friendly. The roadway is now much more accessible to pedestrians and bicyclists while maintaining much of the mobility that was in place for motorized vehicles.

3.3 Case Studies

Two more case studies are presented to show how different RSAR projects differed from one another but still followed the same process. The two case studies are Centerville City and Monticello City.

3.3.1 Centerville City

The segment of the I-15 Frontage Road selected for the RSA runs from Lund

Lane on the North to Porter Lane (400 South) on the South, a distance of about three miles. The street is classified as an urban arterial, which provides access to residential neighborhoods, small businesses and restaurants, and serves as a corridor linking Farmington and Centerville. The street intersects other major arterial streets, major collectors, and local streets. There are two distinct land usages through which the street traverses. The land usage of the northern segment primarily provides access to Farmington and Centerville residential neighborhoods from the Market Place Drive/Parrish Lane intersection to Lund Lane and the land usage of the southern segment is comprised of commercial property from Porter Lane to the Market Place Drive/Parrish Lane intersection. The Annual Average Daily Traffic (AADT) volume for the intersection of Market Place Drive and Parrish Lane for 2004 is 17,470 vehicles per day (VPD). The Annual Average Daily Traffic (AADT) volumes for the Frontage Road are not currently available.

The formal RSA team was comprised of the following individuals: Roland Stanger – FHWA Utah Division Safety Engineer, Steve Thacker – City Manager, City of Centerville, Randy Randall – Public Works Director, City of Centerville, Neal Worsley – Police Chief, City of Centerville, Frank Pyle – Utah LTAP, and Josh Jones – Utah LTAP.

Traffic on the I-15 Frontage Road is comprised of a wide variety of users. The road serves commuters, residents, bicyclists and pedestrian traffic, with some heavy equipment and truck traffic as well. The majority of commuters travel through Centerville from Farmington on the north end, traveling southbound in the morning and northbound in the evening.

The law enforcement representative on the RSA Team, Police Chief Neal Worsley, mentioned that the commuters seem to travel 10-15 mph over the posted speed limit. This is a concern for the police department due to the local resident, bicyclist, and pedestrian use. He suggests the speed limit be lowered to 40 mph and adding bike lanes for that reason.

Contact was made with Mr. Randy Randall, Centerville public works director, to discuss any operations issues in terms of snow removal, trash collection, and signal operations, along with any safety concerns. The principal safety concern dealt with the current speed limit with bicycle and pedestrian use. The principal maintenance issue was repainting of pavement markings. These conditions were observed during the field RSA review. The key findings and suggestions of the RSA are summarized in Table 3.5.

As a result of RSA team survey and further review of the RSA team findings by Utah LTAP, a list of the suggested immediate and long-term safety improvements was provided. The suggested safety improvements should be implemented upon review by the Centerville City officials and engineers to decide which improvements will be implemented within existing budget and proposed capital improvements.

Suggested Immediate Safety Improvements:

1. Upgrade signage and pavement marking
    a. Address Signs to Standard (MUTCD: D3-1).
    b. Reduce Speed Ahead Sign to new Standard (MUTCD: W3-4, W3-5 or W3-5a).
    c. Match signing and pavement marking.

   d. Reposition street signs to allow for more road clearance.
   e. Bring pavement markings to Standard.
   f. Reposition Speed Limit sign where speed limit changes (city boundary).
   g. Position Stop Bar closer to intersection.
2. Improve Sight Triangle
   a. Fence at Porter Lane westbound traffic
   b. Remove or trim tree at 1175 N Frontage Road.
   c. Prune trees in islands to provide better visibility.
3. Install additional signage
   a. Double Arrow Sign (MUTCD: W1-7).
   b. Duplicate Traffic Sign on opposite side of sign.
   c. One more chevron sign (MUTCD: W1-8).
   d. Type II Object Marker (MUTCD: OM2-2).
4. Upgrade ADA truncated domes to new Standard.
5. Conduct speed study on Frontage Road to make speed limit more consistent

Suggested Long-Term Safety Improvements:

1. Consider new “pavement marking” design for lanes to allow for two lanes.
2. Consider new layout for turn lanes, to improve safety.
3. Install crosswalk at Market Place Drive and Frontage Road intersection.
4. Construct bike lanes and determine if Frontage Road parking for park is needed.

3.3.2 Monticello City

The segments of the 200 North/200 West/200 South selected for the RSA begins on Main Street and 200 North where there is a school crossing guard and a school zone with flashing lights. The segment then runs west to 200 West, the location of Monticello Elementary School which includes the pickup/drop-off area at the school. The segment of 200 West then goes south for four blocks with one school crossing on Center Street, which is an emergency vehicle route to reach the San Juan County Hospital. The high schools teacher and student parking lots are divided by 200 West and a significant stream of students occur during peak pick-up/drop off times across the street. From 200 West and 200 South, the route continues east on 200 South back to Main Street.

The formal RSA team was comprised of the following individuals: David Bronson – San Juan County Surveyor, Benny Musselman – Street Superintendent, Kent Adair – City of Monticello Police Chief, Brad Randal – City Councilman, Lance Hatch – Monticello Elementary School Principal, Frank Pyle – Utah LTAP, and Josh Jones – Utah LTAP.

Contact was made with Mr. Lance Hatch, Monticello Elementary School Principal, and Mr. Benny Musselman, Street Superintendent, to discuss any operational issues in terms of snow removal, trash collection, and signal operations, along with any other concerns. The principal issue they cited was the high snow accumulation around the elementary drop-off/pick-up area during the winter months. This condition was considered during the field RSA review.

The key findings and suggestions of the RSA are summarized in Table 3.6. These suggestions do not account for jurisdictional domain between UDOT and Monticello City.

The following suggested safety improvements by the RSA team should be implemented upon review by Monticello city officials and engineers to decide which improvements will be implemented within existing budget and proposed capital

Table 3.5 Summary of Selected Safety Issues and Suggestions for Centerville City.

NO.	SELECTED SAFETY ISSUES (Number & Description)	RISK RATING	SUGGESTIONS
1	Signage & Pavement Marking Upgrades: • Retro-reflectivity • Break away posts • Pedestrian crossings • Sign visibility, placement • Object Marker Sign • Additional Warning Signs • No STOP bar	C	• Upgrade signs to new MUTCD requirements & post assemblies. • Repaint pavement markings. • Install pedestrian crosswalk. • Relocate sign or fixed object outside of clear zone area • Install Type II Object Markers • Install Additional Warning Signs • Install Chevron sign • Install STOP bar
2	Sight Triangle • Trees and Fences obstructing view	D	Trim trees & remove elements blocking visibility.
3	Improve Left Turn Lane Safety	D	• Maintain pavement markings • Design additional lanes and turn lane layout
4	Limited provisions for bicycles	F	Evaluate potential for adding bike lanes
5	Conduct a speed study of Frontage Road, from Market Place Drive/ Parrish Lane intersection to north City Boundary.	D	Provide safe speed limit to accommodate for bicyclists and local traffic.
6	Sidewalk & ADA provisions	D	• Update ADA provisions • Install sidewalk (to avoid walking along roadway)
7	Pedestrian crossings & accessibility	C	Upgrade pedestrian crossing provisions

Risk Rating: A: lowest risk level; B: low risk level; C: moderate-low risk level; D: moderate-high risk level; E: high risk level; F: highest risk level

improvements. A copy of this RSA may also be submitted to Monticello City's insurance group (Utah Local Government Trust) to assist in the safety improvement funding process.

Suggested Immediate Safety Improvements:

1) Prohibit on-street parking on the west side of 200 West from 150 North to 200 North and from 100 South to 200 South.

Table 3.6 Summary of Selected Safety Issues and Suggestions for Monticello City.

NO.	SELECTED SAFETY ISSUES (Number & Description)	RISK RATING	SUGGESTIONS
1	Signage & Pavement Marking Upgrades: • Retro-reflectivity • Break away posts • Sign visibility, placement • Additional Warning Signs	C	• Upgrade signs to new MUTCD requirements & post assemblies. • Repaint pavement markings. • Install additional Warning Signs
2	Parking on-street near schools	D	Prohibit parking on-street near schools
3	Improve Sight Triangle • Trees obstructing view	D	Trim trees & remove elements blocking visibility.
4	Consider a "Safe Routes to School" plan	C	Evaluate a "Safe Routes to School" plan
5	Sidewalk & ADA provisions	C	Update ADA provisions and transition plan
6	Consider a walkway for high School students on 200 South.	B	Evaluate a walkway for high School students on 200 South.
7	Sight triangle concerns at intersections	B	Restrict parking near intersections
8	Short school zone on Main Street at school crosswalk	C	Lengthen school zone on Main St. at the school zone.

Risk Rating: A: lowest risk level; B: low risk level; C: moderate-low risk level; D: moderate-high risk level; E: high risk level; F: highest risk level

2) Sign upgrade and install.

   a) Install a school crossing sign.

   b) Replace SCHOOL sign with MUTCD S4-3FYG.

   c) Replace crosswalk sign with MUTCD S1-1FYG.

3) Sight triangle and right of way concerns.

   a) Trim and clean up trees and shrubs to improve sight distance.

   b) Prohibit parking at corner.

4) Lengthen school zone on Main St.

5) Develop a "Safe Routes To School" plan (to include Elementary School and High School).

Suggested Long-Term Safety Improvements:

1) Install a walkway on 200 South.

An online meeting was held on March 2, 2009 with Monticello City to review the report and discuss which suggested safety improvements will be implemented. The suggested safety improvements along with Monticello City's plan of action are shown in Table 3.7.

Currently, Monticello City is performing studies on the paths students take to and from school. This includes tracking the students distance and time. This information will be used in improving the safe route to school and presented to the School Board and PTA. Monticello City is making the changes it needs to meet the warrant qualifications for reduced speed in school zone. A chain fence has been approved for installation at Main St. and 200 North to protect from drop-off.

Table 3.7 Monticello City Proposed Actions.

NO.	SUGGESTED SAFETY IMPROVEMENT	PROPOSED ACTION
1	Some signs are not in compliance with current MUTCD standards. Additional school signs would help drivers be more aware of the surroundings. (Figures 4, 5, 7, 9 and 10)	In process of replacing school zone signs. Process includes working with current budget and grant submission.
2	The trees and shrubs are creating a sight triangle problem.(Figures 12 and 13)	In process of getting permission from landowners to trim trees and shrubs.
3	On school routes the transitions from curb to the roadway don't meet ADA standards. (Figures 6, 8 and 11)	Included in grant proposal and budget upgrade.
4	Both of the schools on 200 West allow for on street parking across from and next to the school (Figures 9 and 14)	Currently limited on allowed space for parking. Considering performing an accessibility study.
5	Trim tree for better visual of pedestrian signal (Figure 10)	In process of getting permission from landowners to trim trees.
6	Investigate a "Safe Routes To School" plan for Monticello elementary school. (Figure 9, 10 and 16)	Applied for a Safe Routes To School (SR2S) grant to improve school route. Currently performing preliminary studies.
7	Consider a walkway on 200 South for the high school students. (Figure 15)	Included in grant proposal. Tentatively planned for Fall 2010.
8	Consider extending the no parking zone on the northwest corner of 200 South and Main St. due to sight distance triangle concerns. (Figure 17)	Currently in construction phase, including signage upgrades.

3.4 Urban Arterial/Collector Reviews

The urban setting was the most complex RSA's that were performed because of the complex nature of the roads. Each site had very unique attributes, which required a different approach to the RSA. Schools needed extra attention and different checklists to look at the needs of the students. Signing and pavement markings were looked at more closely for standards.

Extra visits to school to analyze routing plans, bus drop off areas, parent pick up area, and the walking patterns of the students including all crosswalks. Contact was also made with principles to get their point of view concerning the safety of their students. Extra emphasis was also made on the pedestrian and bicycle facilities because each city had goals of improving both functions. For in Salt Lake City pedestrian lights (HAWK) were recommended on the road because the residents voiced concern about crossing the road with limited vehicle gaps. Table 3.8 shows each urban site and the reason the RSA was performed.

From the final reports written for the 5 RSA's in Table 3.9 common safety issues were chosen to show the different safety issues that were associated with urban sites. One issue encountered in Salt Lake City was an inconsistent cross–section forcing vehicles to merge. The recommendation was to introduce a road diet on the road by taking away a lane in both directions to add an auxiliary lane and bike lanes. Table 3.9 shows different safety issues with the suggested improvement from the five reports.

Table 3.8 Urban RSAR Sites.

Local Agency	Location Description	Reason for RSA
Centerville City	Frontage Road along the east side of I-15 in Centerville, a distance of about 4 miles.	Future development is planned at the main intersection in the segment.
Monticello City	Ten block segment in Monticello City.	An Elementary School and High School are separated by 3 blocks. The study was done to provide better safety for the students.
Pleasant Grove City	A minor arterial roadway that bisects the city of Pleasant Grove.	A proposed intersection at a Junior High and safety concerns along the segment.
Salt Lake City	A minor arterial roadway along the east bench of Salt Lake City. The Segment starts at 1300 East from South Temple to 2100 South.	The segment was recently turned over to the city for maintenance and operation. The study was done for future safety improvements.
South Weber City	State Road 60 (South Weber Drive) 3 miles of a narrow winding road	Increased concern from the high AADT combined with the demographics of the road. It has also become a popular bicycle route.

Table 3.9 Selected Safety Issues for Urban Sites.

Cited Safety Issues (Description)	Recommended Improvement	Crash Reduction
Parking on-street near schools	Prohibit parking on-street near schools	22%
Traffic signal conditions	Upgrade signal heads	25%
Canal crossing: Unprotected or Substandard guardrail	Install guardrail. Widen/Lengthen culvert. Upgrade guardrail.	30% 30% 20%
Inconsistent cross section for a short distance.	Add an auxiliary lane through this section (two way left turn lane).	30%
Sidewalk & ADA provisions	Update ADA provisions and transition plan	20%
Pavement Gutter Drop-offs: 12 to 18 inch edge drop offs	Upgrade & improve driveway access bridges to residents.	25%
Traffic Signal conditions	Upgrade signal heads	25%

3.5 Intersection Reviews

Intersections are the most dangerous segments on the road system and have the highest probability of fatal crashes. Two of the sites were reviewed because of prior crash history. Three other sites reviewed had T-intersections with skew angles with the probability of crashes. Table 3.10 shows all of the intersections reviewed and the reason for each review. The main safety issue for the intersections was the skew angle that three of the sites had. The Francis City T-intersection was located on top of a hill with a skew angle of 30 degrees with inadequate sight distance and the tendency for vehicles to encroach on the other lane while making the turn. The suggested improvement was to turn one of the roads into a one way street eliminating the encroachment of vehicles and the inadequate sight distance. Table 3.11 shows common safety issues associated with the 5 intersections reviewed.

Table 3.10 Intersection RSAR Sites.

Local Agency	Location Description	Reason for RSA
Enoch City	Intersection of Minersville Rd. and Mid Valley Rd.	The city wanted to make the main intersection safer with a low budget.
Francis City	Intersection of Hilltop Road and State road 32.	The skew angle in the T-intersection has a high probability of crashes.
Layton City	Intersection at Church St. and Fairfield Rd.	31 accidents in 5 years, 10 accidents last year (2007). The intersection is scheduled for re-alignment in 2011-2012.
Salt Lake County	Intersection of 2000 East and Siggard Drive (3650 South)	Has two T-intersection joined together but offset making the intersection hard to traverse by pedestrians and vehicles.
San Juan County	Intersection of county and state road.	1 Fatal Crash.

Table 3.11 Selected Safety Issues for Intersections.

Cited Safety Issues (Description)	Recommended Improvement	Crash Reduction
Lighting at intersection	Improve lighting at intersection	42%
Improve intersection safety	Realign intersection legs	18%
Sidewalk & ADA provisions	Update ADA provisions	20%
Turn lane safety	Improve right turn lane	27%
Guardrail substandard	Raise guardrail to proper height.	23%

3.6 Rural Road Reviews

The rural reviews were the simplest because they generally had a smaller range of road users with truck traffic being the leading user. One exemption was the Grand County RSA with the road mainly serving recreational users. Another unique site was the Iron County RSA that is a gravel road and is open half of the year. Table 3.12 shows all of the rural roads reviewed and the reason for the RSA.

One main issue with rural roads was road runoffs resulting in fatal crashes. Suggested improvements included installing rumble strips, clearing the right-of-way, improving curves, and upgrading or installing guardrails. Another safety issue was the interaction between trucks and small cars. Table 3.13 shows common safety issues associated with the eight rural roads reviewed.

Table 3.12 Rural RSAR Sites.

Local Agency	Location Description	Reason for RSA
Carbon County	Lower Miller Creek Road (2.8 miles) and Old Wellington Road (3.8 miles)	High crash rate.
Box Elder County	The road is classified as a minor arterial connecting I-15 with Highway 83.	A Proctor Gamble plant is being built on the road. The study was done to improve safety for the increased truck traffic.
Grand County	Kane Creek Road. Starting at the intersection of 500 West and Kane Creek Blvd. in Moab City, goes to end of pavement.	The wide range of users includes bicyclist, ATV's, Jeeps, and motor homes. Combined with a high AADT on the road. 1 fatality.
Hurricane City	The segment runs for 1.5 miles and has multiple road users.	Increased use from the new reservoir to the west of the road.
Iron County	Triangle intersection area made up of a network of dirt roads.	The steep switchbacks are a safety hazard.
Juab County	Runs parallel to I-15 and runs approximately 2 miles to include a new subdivision and school zones around Rocky Ridge Road.	Heavy truck traffic due to big gravel pits. Used as a by-pass for I-15. The road has major rutting and ice builds up in the ruts.
Uinta County	Curve at 17500 E. 2250 S. on the Ft. Duchesne - Randlett Hwy.	High AAADT and 3 fatalities.
Weber County	1200 S from 4700 W to 5900 W	2 fatalities.

Table 3.13 Selected Safety Issues for Rural Roads.

Cited Safety Issues (Description)	Suggested Improvement	Crash Reduction
Close proximity of the canal to the road segment	Install delineators along the canal Install a rumble strip on the canal side	34% 26%
Improve curve safety.	Conduct speed study. Extend guardrails on bridge for inside and outside of curve.	20% 35%
Pavement condition	Repair ruts in pavement.	28%
Improve right-of-way area.	Replace mailboxes with breakaway crash worthy mailboxes. Remove large rocks.	25% 30%
Guardrail doesn't meet length of need.	Extend guardrail.	N/A
Drainage problems along the segment.	Evaluate pavement condition. Replace/Fix culverts.	N/A

3.7 Lessons Learned

The RSA's conducted in Utah created many learning opportunities. The wide variety of intersections, urban roads, and rural roads helped the RSA process become applicable to all situations. Having a wide variety of personnel as part of the RSA team brought in the diversity in experience that a RSA needed in order to look at every angle of safety concerns presented. The RSA teams considered the perspective from Traffic Engineers, city engineers, elected officials, law enforcement officers, local state Department of Transportation personnel, county and city road workers, and neighborhood locals. Thinking outside the box greatly helps with RSA's. It opens the door to better able discover every safety concern and to address those concerns. Local RSA team members provided the most insight into how the roads or intersections are performing and what impacts were affecting the road. An added benefit of training local representatives on each project is they will be able to apply the lessons they learned on all of the roads in their local network. The local police force was very instrumental in providing information about current traffic conditions. When any schools were involved the principle's input was very useful to understanding the behavior of the students.

It is important to have all of the preliminary data collected, compiled, and processed before beginning the RSA Team inspection of the selected road segment or intersection. Having all the data available to the RSA team will assist the team in the decision making process of offering suggestive safety improvements. Communication lines need to be established with the police and road departments to get the data pertaining to crashes and future projects. Without all of the information of the road, recommendations could be detrimental to the road or intersections.

The balance of finding the perfect amount of RSA team members was always present. A larger team will give more insight into the RSA and helps give every user of the road representation. Larger teams do make it harder to come to a mutual agreement on recommendations and make it harder to schedule RSA site visits with members' schedules. Smaller teams allow for more flexibility with scheduling and it is easier to come to a mutual agreement.

When conducting an RSA for several road segments and intersections it is important not to forget that every RSA is equally as important as the first or biggest segment. It is easy to lose yourself in a larger road segment. Larger can mean more important in the public's eye, more exposure from the media, etc… It is important to not let such outside influences affect the RSA's as a whole. If anything is to influence the importance of one road segment over another it should be crash rates, annual traffic count data, or other safety influences or concerns.

CHAPTER 4

RSAR QUANTIFICATION TOOL

As road safety audits have been implemented by agencies across the country, transportation professionals have realized that they are an effective tool for proactively improving the future safety performance of a roadway. However, there has been limited study of the benefits gained through road safety audit recommendations on existing roadways. A quantification tool will give local governments a way to quantify the risk on their roadways and to find the potential benefits gained through the safety recommendations. Currently, there is difficulty quantifying risk on roadways that do not have extensive crash histories associated with them. The tool is the first step from a qualitative approach to a quantitative approach. Usually multiple factors are involved with crashes and can complicate the process of finding solutions. This requires a broad approach that looks at multiple areas on the roadway that cause risk.

4.1 Methodology

In this chapter, a tool was developed to help quantify the risk on an urban roadway during an RSAR evaluation. The RSAR tool was developed and validated by using four urban RSAR projects that the Utah LTAP Center conducted around the state of Utah. The four urban cities were Salt Lake City, South Weber City, Pleasant Grove City, and Centerville City. After the evaluation of each urban RSAR, common safety risks were identified to find similarities between the projects. The common safety risks were then phrased into questions to be incorporated into a RSAR checklist. The questions are

Table 4.1 FHWA Risk Rating Correlated with the RSAR Risk Rating Tool.

FHWA Risk Rating		RSAR Risk Rating	Numerical Value of Each Question
A	Lowest Risk Level	None	0.00
B	Low Risk Level	Low	0.15
C	Moderate-Low Risk Lever	Medium	0.50
D	Moderate-High Risk Lever	Medium	0.50
E	High Risk Rating	High	0.85
F	Highest Risk Rating	High	0.85

then quantified in the RSAR tool by assigning different degrees of risk. There are four different risk ratings that can be chosen that correlate with FHWA's risk rating system as shown in Table 4.1. The numerical numbers associated with each RSAR risk rating were chosen on a 0 to 1 scale to represent risk on a percentage scale. The high risk rating shows a 85% risk to the given question. Zero percent risk was chosen for a risk rating of none so that it would not have an effect on the category risk rating.

4.2 Questions

To help identify the high risk locations the RSAR risk assessment tool is split into seven general categories that include:

- Signs
- Traffic Control Devices (TCD)
- Pavement
- Roadside Hazards
- Sight Distance
- Cross-Section
- Pedestrian/Bicycle

Each category the practitioner is asked five questions and to assign a risk rating. It is not intended to be all-inclusive, but can be used as a starting point. The purpose of a safety review is to flag features that need to be investigated further to determine what, if any, action should be taken. Judgment is needed in applying this list. There may be other factors identified during a review contributing to the safety of the road. The checklist asks a series of questions to stimulate thinking about possible safety issues. The questions were obtained from observations during the multiple RSARs and supporting literature. Each question under their associated category are tabulated below.

The following questions are used to get a category risk rating for the condition and presence of signs on the roadway:

- Is there inadequate signing?
- Is there missing or faded signs?
- Do any signs need to be relocated?
- Is there poor sign visibility?
- Are signs up to MUTCD standards?

The following questions are used to get a category risk rating for the effectiveness of the traffic control devices:

- Is there Inadequate TCDs?
- Is there Inadequate signal timing?
- Are there any unwarranted signals?
- Are there any traffic light obstructions along the section?
- Is there adequate lighting around TCDs?

The following questions are used to get a category risk rating for the condition of the pavement:

- Are there inadequate or improper pavement markings?
- Is there any rutting along the segment?
- Is there a rough crossing surface?
- Are there inadequate draining along the section?
- Is there inadequate pavement maintenance?

The following questions are used to get a category risk rating for the presence of roadside hazards:

- Are there inadequate culverts and/or guardrails?
- Are there any utility objects too close to roadway?
- Are there inadequate gutter depths?
- Are there any natural objects too close to roadway?
- Are there any unprotected waterways close to the road?

The following questions are used to get a category risk rating for the sight distance on the roadway:

- Is parking creating sight distance issues?
- Are there any intersections that have restricted sight distances?
- Is there limited sight distance on any curves?
- Are structures restricting sight distance?
- Are trees or shrubs restricting sight distance?

The following questions are used to get a category risk rating for the functionality of the road:

- Are there any improperly located driveways?
- Is there an inconsistent cross section?
- Is there inadequate roadway design for traffic conditions?
- Is there inadequate shoulders?
- Are there any skew angles at intersections?

The following questions are used to get a category risk rating for the effectiveness of pedestrian and bicycle protection:

- Are sidewalks broken and uneven?
- Are there limited ADA provisions?
- Is there inadequate pedestrian protection
- Is there inadequate lighting for bicycle protection?
- Are there limited bicycle provisions?

4.3 Weighting

A review was made of two recognized references that set forth accident reduction factors for various types of roadway safety improvements. These references are a research report by the Kentucky Transportation Center entitled "Development of Accident Reduction Factors – KTC 96 13" (Agent et al. 1996) and Report No. FHWA-SA-07-015 entitled "Desktop Reference Manual for Crash Reduction Factors" (FHWA 2007). The crash reduction percentage is the affect that the suggested improvement would have if implemented. Only crash reduction factors that reduced all crashes were used except for the pedestrian/bicycle category, factors that reduced pedestrian and bicycle crashes were used. Each category has a different effect on the safety of the road. The tool looks at which categories have the highest potential of reducing crashes from crash reduction factors. As shown in Table 4.2 all the safety countermeasures that were related to the sign category in the RSAR tool were averaged to find the average crash reduction factor. The weights were obtained by dividing each categories crash reduction factor by the sum of all the category crash reduction factors.

Table 4.3 shows the calculated weights and average Crash Reduction Factor (CRF) for each category. Also shown is the category weight when no Traffic Control Devices (TCD) are present. Sight distance had the lowest weight percentage with 5.65% and cross-section had the highest weight percentage at 17.44%.

Table 4.2 Crash Reduction Factors of Safety Countermeasures for Signs Category.

Category	Safety Countermeasure	CRF	Average	Weight %
Signs	Install curve advance warning signs	30	22.89	11.19%
Signs	Install curve advance warning signs(flashing beacon)	29		
Signs	Install curve advance warning signs(advisory speed)	30		
Signs	Install post-mounted delineator (curve)	25		
Signs	Install delineators (general)	11		
Signs	Install dynamic/variable speed warning signs	46		
Signs	Install illuminated signs	15		
Signs	Install guide sign (general)	15		
Signs	Install pavement condition warning signs	5		

Table 4.3 Category Weights.

Category	Average CRF	Weight %
Signs	22.89	11.19%
TCD	30.14	15.49%
Pavement	32.4	16.65%
Roadside Hazard	30.89	15.87%
Sight Distance	11	5.65%
Cross-Section	33.94	17.44%
Pedestrian/Bike	33.33	17.13%

4.4 RSAR Risk Assessment Score

All of the questions in each category are summed together and multiplied by the category weight. As shown in Table 4.3, each risk rating is assigned a number. To calculate the risk for each category the five questions are summed together. The category risk rating score is calculated by Equation 4.1. The category risk rating calculates the potential risk for each category.

$$\text{Category Risk Rating} = \sum \text{Question Score} * \text{Category Weight} \qquad \text{Equation 4.1}$$

4.5 Case Studies

The RSA risk rating tool was developed to be used for an entire RSA project. The two projects that are highlighted in this section are Salt Lake City and South Weber City. For each project the selected safety issues and safety recommendations are shown with their correlated risk and suggested safety improvements. Not all of the safety recommendations were implemented but the tool is used to show agencies the benefits that could be gained from the safety recommendations. Also not all selected safety issues observed during the RSAR are highlighted in the tables but only the ones that had safety recommendations.

4.5.1 Salt Lake City

Table 4.4 shows the main safety issues observed during the RSAR with their associated risk rating and safety recommendations for each safety issue.

The RSA risk assessment tool is shown in Table 4.5 with the associated risk rating for each question. The tool was able to assess all of safety issues except for the transit stop locations. The only safety issue deemed to have a high risk rating was the limited provisions for bicycles.

Table 4.4 Selected Safety Issues with Associated Risk Rating.

NO.	SELECTED SAFETY ISSUES (Number & Description)	RISK RATING	SUGGESTIONS
1	Signage & Pavement Marking Upgrades: • Retro-reflectivity • Break away posts • Pedestrian crossings • Sign visibility blockage	C	• Upgrade signs to new MUTCD requirements & post assemblies. • Repaint pavement markings. • Improve consistency in pedestrian crossing markings. • Trim trees & remove elements blocking sign visibility.
2	Pavement gutter drop-offs were 12 to 18 inches.	B	Upgrade & improve driveway access bridges to residents.
3	Alignment & proper functioning of Pedestrian Count Down Signals	C	Maintain & realign pedestrian signals.
4	Limited provisions for bicycles	F	Evaluate potential for adding bike lanes
5	Business accesses too close to intersections	D	• Develop & initiate access management policy. • Consider closing hazardous accesses
6	Sidewalk & ADA provisions	C	• Reconstruct broken sidewalk • Update ADA provisions
7	Transit stop locations	E	Work with UTA to move transit stops to far side of intersections
8	Variable street cross sections and variable number of lanes	D	Evaluate street cross section in conjunction with major street improvements.
	Pedestrian crossings & accessibility	C	Upgrade pedestrian crossing provisions
10	Traffic Signal conditions	D	Upgrade signal heads

Risk Rating: A: lowest risk level; B: low risk level; C: moderate-low risk level; D: moderate-high risk level; E: high risk level; F: highest risk level

The analysis for the RSA conducted in Salt Lake City is shown in Table 4.6. For each category the potential risk before the RSA recommendations and after the safety recommendations are calculated. Also shown in the table is the category reduction. RSARs usually identify low cost safety improvements with signs and pavement markings. Other low cost safety improvements included upgrading signal heads and

Table 4.5 Risk Rating Tool.

Category	Question	Risk Rating
Signs	Is there inadequate signing?	Medium
Signs	Is there missing or faded signs?	Low
Signs	Do any signs need to be relocated?	Low
Signs	Is there poor sign visibility?	Medium
Signs	Are the signs up to MUTCD standards?	Medium
TCD	Is there Inadequate TCDs?	Medium
TCD	Is there Inadequate signal timing?	Low
TCD	Are there any unwarranted signals?	Low
TCD	Are there any Traffic light obstructions along the section?	Low
TCD	Is there adequate lighting around TCDs?	Low
Pavement	Are there inadequate or improper pavement markings?	Medium
Pavement	Is there any rutting along the segment?	Low
Pavement	Is there a rough crossing surface?	Low
Pavement	Is there inadequate draining along the section?	Low
Pavement	Is there inadequate pavement maintenance?	Low
Roadside Hazard	Are there inadequate culverts and/or guardrails?	Low
Roadside Hazard	Are there any utility objects too close to roadway?	Medium
Roadside Hazard	Are there inadequate gutter depths?	Medium
Roadside Hazard	Are there any natural objects too close to roadway?	Medium
Roadside Hazard	Are there any unprotected waterways close to the road?	None
Sight Distance	Is parking creating sight distance issues?	None
Sight Distance	Are there any intersections that have restricted sight distances?	None
Sight Distance	Is there limited sight distance on any curves?	None
Sight Distance	Are structures restricting sight distance?	Low
Sight Distance	Are trees or shrubs restricting sight distance?	Medium
Cross-Section	Are there any improperly located access points or driveways?	Medium
Cross-Section	Is there an inconsistent cross section?	Medium
Cross-Section	Is there an inadequate roadway design for traffic conditions?	Medium
Cross-Section	Is there inadequate shoulders?	Low
Cross-Section	Are the any skew angles at intersections?	Low
Pedestrian/Bicycle	Are sidewalks broken and uneven?	Medium
Pedestrian/Bicycle	Are there limited ADA provisions?	Medium
Pedestrian/Bicycle	Is there inadequate pedestrian protection	Medium
Pedestrian/Bicycle	Is there inadequate lighting for bicycle protection?	Low
Pedestrian/Bicycle	Are there limited bicycle provisions?	High

Table 4.6 Categories Before and After Risk Rating.

Category	Potential Risk Before	Potential Risk After	Reduction (%)
Signs	21.2	15.29	28%
TCD	17	9.3	45%
Pavement	18.3	10	45%
Roadside Hazard	26.2	15.1	42%
Sight Distance	3.7	0.9	76%
Cross Section	31.4	13.1	58%
Pedestrian/ Bicycle	42.8	7.7	82%
Total	160.6	71.3	56%

maintaining or realigning pedestrian signals. Pedestrian/Bicycle category had the greatest reduction at 82% with signs having the lowest reduction at 28%. If all the safety recommendations were implemented the potential overall risk reduction is 56%.

4.5.2 South Weber City

Table 4.7 shows the main safety issues observed during the RSAR with their associated risk rating and safety recommendations for each safety issue.

Table 4.7 Selected Safety Issues with Associated Risk Rating.

NO.	SELECTED SAFETY ISSUES (Number & Description)	RISK RATING	SUGGESTIONS
1	Signage & Pavement Marking Upgrades: • Retro-reflectivity • Break away posts • Sign visibility, placement • Additional Warning Signs	C	• Upgrade signs to new MUTCD requirements & post assemblies. • Repaint pavement markings. • Install additional Warning Signs • Install Chevron Signs
2	Improve Sight Triangle • Trees obstructing view	D	Trim trees & remove elements blocking visibility.
3	Consider "Narrow School Route"	D	Define place for school children to walk.
4	Limited provisions for bicycles	F	Adding bike lanes
5	Conduct a speed study and ball bank of South Weber Drive for the purpose of updating signage and speed limit if needed.	D	Provide safe speed limit to accommodate for bicyclists and local traffic.
6	Sidewalk & ADA provisions	C	Update ADA provisions and transition plan
7	Investigate right of way boundary	B	Improve area for right of way rights
8	Clear zone concern • Remove large rocks	C	Remove large landscaping rocks to improve clear zone safety

Risk Rating: A: lowest risk level; B: low risk level; C: moderate-low risk level; D: moderate-high risk level; E: high risk level; F: highest risk level

The analysis for the RSAR conducted in South Weber City is shown in Table 4.8. Pedestrian/Bicycle category had the greatest reduction at 92% with pavement and cross section having the lowest reductions at 43%. Overall the safety recommendations will provide a potential reduction in risk of 66%.

4.5.3 Analysis

The final analysis of the RSAR risk assessment tool is shown in Table 4.9. Two additional urban RSAR projects were added to analyze what categories had the most reduction. It shows that low cost safety measures were recommended the most with signs and sight distance having an average reduction of over 70%. Pedestrian and bicycle also showed a reduction of over 70% as more attention was made to pedestrian and bicycle safety. High cost categories like traffic control devices, pavement, and cross section showed the lowest reduction but did show improvement. The total reduction for all categories showed an average reduction of 62%.

Table 4.8 Category Before and After Risk Rating.

Group	Potential Risk Before	Potential Risk After	Reduction (%)
Signs	45.1	5	89%
TCD	0	0	0%
Pavement	41.4	23.8	43%
Roadside Hazard	75.12	12	84%
Sight Distance	18.2	1.4	92%
Cross Section	167.7	95.4	43%
Pedestrian/ Bicycle	111.9	18.3	84%
Total	459.4	155.9	66%

Table 4.9 Final Analysis of the Risk Assessment Tool.

	Salt Lake City		South Weber City		Centerville City		Pleasant Grove City		
Group	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Average Reduction**
Signs	21.2	15.29	45.1	5	54.4	6.6	19.4	3.5	72%
TCD	17	9.3	0	0	8.7	8.7	22.5	17	23%
Pavement	18.3	10	41.4	23.8	15	6	18.3	10	48%
Roadside Hazard	26.2	15.1	75.12	12	6.7	1.4	26.2	7.1	70%
Sight Distance	3.7	0.9	18.2	1.4	18.3	3.2	8.5	1.7	83%
Cross Section	31.4	13.1	167.7	95.4	36.7	21.1	31.4	16.6	48%
Pedestrian / Bicycle	42.8	7.7	111.9	18.3	79.2	6.2	36.8	24.8	73%
Total	160.6	71.3	459.4	155.9	219	53.2	163.1	80.8	62%

CHAPTER 5

CONCLUSION AND FUTURE INVESTIGATIONS

5.1 Conclusion

As roadway safety is being brought to the forefront of the transportation industry RSARs are becoming a major tool for assessing the risk on existing roadways. RSARs are proactive in nature and look to find safety risk before crashes occur. This makes quantifying the risks difficult since a lot of the RSAR projects not have extensive crash histories for before and after studies to be conducted. To improve the ability of decision makers' to assess risk on the roadways, transportation professionals need a tool that can look at the complexity of the roadways.

The Road Safety Audit Grant was instrumental in providing the resources for implementing and demonstrating RSA procedures and techniques to local agencies in Utah and to the Utah Department of Transportation (UDOT). Conduct of the 18 RSA's provided concrete examples of the safety benefits to be realized. The development and provision of the Safety Software Suite to the local agencies provided them with added safety tools with which to continue to conduct RSA's of other facilities. In addition, the participation of UDOT Traffic & Safety Division staff, Roland Stanger – FHWA Safety Engineer, various law enforcement staff, and local consulting firms added greatly to the make-up of the multi-disciplinary RSA teams and to the RSA as a whole. Each are to be commended for their excellent support and involvement.

To be able to assess RSARs, a tool was developed to quantify the benefits gained through the safety recommendations. The quantification tool will be able to analyze the potential risk during the field observations and after the safety recommendations are made. This paper proposes a seven category decision making tool that can help quantify the potential risk observed on the roadway into a number that can be analyzed. Each category has five questions that were obtained from field observations during Utah LTAPs RSA program. For each question a risk rating is chosen depending on the probability of a crash. The risk rating is then quantified with a number that correlates with FHWAs risk rating system. The category risk is calculated by summing the risk ratings and multiplying by the category weight.

The RSAR risk assessment tool was performed on four different urban projects in Utah. The results show that all of the categories had potential risk reductions after the safety recommendations were made. The categories with the most reduction were centered on low cost safety improvements of maintenance (sight distance and pavement markings) and sign improvements. Also pedestrian and bicycle safety was given more attention due to the urban setting of the RSARs.

The RSAR risk assessment tool will help practitioners with a specialized checklist developed for urban settings. The tool will help decision makers in targeting areas of the roadway that showed high risk. It will also help practitioners chose safety projects based on their most high risk roadways.

5.2 Future Investigations

Not much research has been done on quantifying the benefits gained from conducting a RSAR. This tool will help practitioners and researchers but this was the first step for quantifying RSAR recommendations. Future investigations can look at ways to help calibrate the tool to actual benefits gained from the RSA recommendations. The following are ideas for future investigations:

- Provide evidence that RSAR tool helped reduce crashes by conducting a before and after studies on all the RSAR projects using at least 3 years of crash data.
- Compare the reduction in the RSAR tool to the reduction in total crashes. This will test and calibrate the weighting of the different subjects in the RSAR tool.
- Develop a RSAR tool for intersections and rural roadways using the methodology presented in this research.

REFERENCES

Agent, K., Kikiforos S., and Jones, S. (1996, June). "Development of accident reduction factors." *Research Report No. KTC-96-13*. Kentucky Transportation Center, Lexington, Kentucky.

ADB (Asian Development Bank). (2003). "*Road Safety Audit for Road Projects, an Operational Tool Kit.*" Manila, Philippines.

Crowe, B. (2009, Winter). RSA Newsletter. *RSA Status, 2,* 4.

FHWA. (2006). "FHWA Road Safety Audit Guidelines*.*" *Report No. FHWA-SA-06-06*, Washington, D.C.

FHWA. (2007). "Desktop reference for crash reduction factors." *Publication No. FHWA-SA-07-015,* Washington, D.C.

FHWA. (2008). "Tribal road safety audits: case studies.*"* *Report No. FHWA-SA-08-005*, Washington, D.C.

FHWA Corporate Research and Technology. (2009a). "*Road safety audits (RSA).*" <http://www.fhwa.dot.gov/crt/lifecycle/audits.cfm> (accessed May 2009)

FHWA Highways for Life. (2009b). *Success Story: RSA* <http://www.fhwa.dot.gov/hfl/successstory.cfm?id=49> (accessed June 2009)

Huang, H., Stewart, J., and Zegeer, C. (2002). "Evaluation of lane reduction "road diet" measures on crashes and injuries." *Transportation Research Record 1784*. Transportation Research Board. Washington, D.C.

Ksaibati, K., Zhong, C., and Evans, B. (2009). *"*WRRSP: Wyoming Rural Road Safety Program*"*. *FHWA-WY-09/06F*. Wyoming Department of Transportation. Cheyenne, Wyoming.

NHTSA. *"U.S. Transportation Secretary LaHood announces lowest traffic fatalities in six decades*." <http://www.nhtsa.gov/PR/DOT-165-10/> (accessed September, 2010).

Mahgoub, H., Selim, A., And Pramod, K. (2010). *"Quantitative assessment of local rural road safety – case study."* Transportation Research Board. Washington, D.C.

Pietrucha, Martin T., T. R. Pieples, and P. M. Garvey, "Evaluation of Pennsylvania Road Safety Audit Pilot Program", *Transportation Research Record #1734*, Washington, D.C.

SLC Transportation, Salt Lake City Transportation Division. (2010). "*1300 East road safety audit.*" <http://www.slcgov.com/council/announcements/1300_East_PowerPoint.pdf> (June, 2009)

UNECE (United Nations Economic Commission for Europe). (2008). *UNECE Transport Review*. First edition. United Nations. Geneva.

UNDESA (United Nations Department of Economic and Social Affairs). (2010). IRU RESOLUTION on the *"UN Decade of Action for Road Safety."* United Nations. Geneva.

Wilson, E. M., and Lipinski. M. E. (2004). *NCHRP Synthesis 336: Road Safety Audits, A Synthesis of Highway Practice.* Transportation Research Board, National Research Council. Washington, D.C.